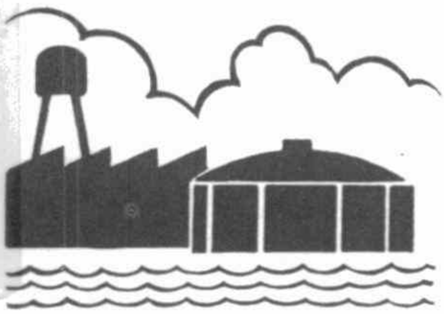

24th ONTARIO INDUSTRIAL WASTE CONFERENCE

MAY 30 - JUNE 1, 1977
TORONTO, ONTARIO

PROCEEDINGS

Ontario
Ministry of the Environment

Hon. George A. Kerr, Q.C.
Minister

K. H. Sharpe
Deputy Minister

P R O C E E D I N G S

OF THE

TWENTY - FOURTH

ONTARIO INDUSTRIAL

WASTE CONFERENCE

HELD AT

THE PRINCE HOTEL

TORONTO

MAY 29 - JUNE 1, 1977

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PREFACE TO THE PROCEEDINGS OF THE
24TH ONTARIO INDUSTRIAL WASTE CONFERENCE

Assembling the papers for the printing and distribution of the Proceedings of the 24th Ontario Industrial Waste Conference indicates not only an end but a beginning. As we clear up the unfinished business of this year's Conference, we are simultaneously preparing for our Silver Anniversary coming up next year. I am especially pleased, since this Conference served as my inauguration as chairman, to present to you its Proceedings.

The success of this year's Conference was dependent on the hard work and co-operation of the committee members, session chairmen, and most important, the authors and co-authors, whose contributions are much appreciated. We have broadened our scope of topics since our first Conference in 1954, with our interests and concerns expanded to include water and air pollution abatement, solid waste management related to industrial waste, environmental assessment and parallel subjects. The continued success of the Conference relies on attracting the most progressive thinkers in the industrial waste management field so that the Conference will continue to provide leadership in environmental protection and abatement programs.

The 1977 Ontario Industrial Waste Conference was as successful as ever, attracting delegates from nine of Canada's 10 provinces and six states of the United States. The high calibre of papers and the good organization and execution of the program made for a worthwhile educational experience. Total attendance at the 24th Conference was 515, including 442 registered delegates, 63 spouses, and 10 committee members and staff and media representatives.

For your information, our 25th Industrial Waste Conference will once again be held at the Prince Hotel in Toronto in 1978. The dates will be from June 18 to 21 inclusive. I would like to invite all of those who attended this year's Conference to join us in celebrating our Silver Anniversary.

D. P. Caplice

D. P. Caplice
Conference Chairman

KEYNOTE SPEAKERS

K. H. Sharpe,
Deputy Minister
Ontario Ministry of
the Environment
Toronto

OPENING REMARKS

Ken Sharpe, recently appointed Deputy Minister of Environment Ontario and former chairman of the Conference for the past three years, delivered the opening remarks to the Conference on behalf of the Ministry.

Mr. Sharpe reviewed the programs of the Ministry as they apply to industrial abatement and pollution control. He placed particular emphasis on environmental assessment, pointing out that the Province's Environmental Assessment Act is the only piece of legislation in Canada which is aimed at the prevention of environmental damage through consideration of major undertakings at the planning stage. The logic of the new legislation is that it is easier, faster and more economical to preserve the environment by enlightened planning beforehand than to restore it and combat pollution after-the-fact.

The new Deputy Minister extended greetings to the delegates on behalf of the Government of Ontario and the Minister of the Environment and wished the delegates well in their deliberations over the three days of the Conference.

BANQUET SPEAKER
"Canadians and Their Drugs — A Lighter Look"

Dr. Johnson took a lighter look at the drugs of the 1970s and their effects on Canadians in his address to the annual Conference banquet. Quoting from an abstract of the address — "Canadians ingest, insert, inject and inhale hundreds of millions of dollars of drugs each year. Much of this drug use involves over-the-counter drugs and is unwarranted and can even be dangerous. Who is to blame? The pharmaceutical manufacturer who puts his wonder remedies on the market with little evidence for their therapeutic efficacy, the government who licenses products for sale with no evidence of their medical value, or the consumer, who in his desire to escape from an acid stomach, sweat, or constipation, reaches for the pretty packages containing combinations of "medically proven" ingredients?"

A witty foray into the world of pharmaceutical drug research and marketing, the speaker's address provided food for thought and a welcomed change-of-pace from the weightier deliberations of the Conference proper.

Dr. G. E. Johnson
Professor and Head, Department
of Pharmacology
University of Saskatchewan
Saskatoon

CONFERENCE PLANNING COMMITTEE

Conference Chairman
D. P. Caplice, Director
Environmental Approvals Branch
Ontario Ministry of the Environment

Program Convenor
J. B. Patterson, Supervisor
Industrial Approvals Section
Environmental Approvals Branch
Ontario Ministry of the Environment

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E. W. Turner, Assistant Director
& Supervisor, Industrial Section
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T. D. Armstrong, Manager, Industrial Abatement, Central Region, Environment Ontario
E. T. Barrow, Head, New Technology Unit, Air Resources Branch, Environment Ontario
B. I. Boyko, Manager, Technology & Market Development Section, Resource Recovery, Environment Ontario
J. R. Hawley, Head, Mining & Metallurgy Unit, Pollution Control Branch, Environment Ontario
R. C. Stewart, Manager, Technical Support, West-Central Region, Environment Ontario

SESSION 1

Session Chairman
Prof. R. S. Lang, Faculty of
Environmental Studies
York University, Toronto

THE BERGER INQUIRY:
Scope, Method, Significance
D. J. Gamble
Technical and Environmental Advisor
The Berger Commission
MacKenzie Valley Pipeline Inquiry
Ottawa, Ontario

The Community Approach to Environmental Approval
W. J. Grant
Advisor, Environmental Affairs
Gulf Oil Canada Limited
Toronto, Ontario

The Role of Environmental Assessment in a Major Pulpmill Expansion Program
C. F. Gorham
Director-Technical Development and
Environment
Kimberley-Clark of Canada Limited
Terrace Bay, Ontario

THE BERGER INQUIRY: SCOPE, METHOD AND IMPLICATIONS

by

D. J. Gamble

Technical Advisor,
Mackenzie Valley Pipeline Inquiry,
Ottawa.

INTRODUCTION: THE ROOT OF THE MATTER

In May 1976 when the Mackenzie Valley Pipeline Inquiry held hearings in Calgary, Mayor Rod Sykes noted:

> Canadians seem to be the only people on earth who are constantly pulling themselves up by the roots to see if they are still growing.[1]

Although the mayor was expressing the frustration and impatience felt by many people, his comment is, in fact, an apt description of the methods and aims of the Inquiry conducted by Mr. Justice Thomas R. Berger.

The Inquiry was, after all, charged with the responsibility of assessing the social, economic and environmental impact of a highly complex, massive and technologically innovative project. It would be be the first large diameter, high pressure, thick-walled, chilled gas pipeline. Unlike any other pipeline, it would be buried in ice-rich permafrost. In terms of capital expenditure the project has been described as the largest ever undertaken by private enterprise anywhere. Eventually the gas pipeline corridor is expected to include a number of other transportation systems from an oil pipeline to a highway.

In addition, the pipeline project represents a massive intrusion of industrial development into a relative hinterland with a unique biology and vast wilderness areas. It would pass through lands claimed by Canada's native peoples -- Indian, Inuit and Metis -- and through a territory struggling for political autonomy. The debate it has inspired "is not simply ... about a gas pipeline and an energy corridor it is a debate about the future of the North and its peoples."[2]

Nor are the projects' effects and implications of concern exclusive to the North. The pipeline is being proposed at a time when concern over damage to the environment has become a matter of widespread public interest. It is also a time when the world is faced with what is popularly known as the "energy crisis," a situation that makes rational, long-term planning of resource development and exploitation imperative -- and extraordinarily difficult.

Clearly, a project such as the Mackenzie Valley pipeline requires close and critical scrutiny. Intelligent decisions on the pipeline must be based on an accurate assessment of its impact. Understanding this impact requires information that is thorough in the extreme. If obtaining such information is a long and patience-taxing process, it is so because of the complexity of the issues involved. And if this proves to be frustrating to some, it is also apparent that failing to get at the roots of the matters involved could prove not merely frustrating, but disastrous to many.

Impact assessment is still in its infancy. There is no universally accepted technique for addressing the myriad of complex biological, human and political issues involved in major development proposals. As the Inquiry set about its task of examining each of these issues, of relating them to one another, and of assessing the significance of the whole, it became evident that the development of an appropriate methodology was crucial if the Inquiry was effectively to discharge its responsibilities. If we look closely at how the Berger Inquiry was conducted, it becomes obvious that we have crossed an important threshold in developing a method for assessing impact.

As in any quest for knowledge, the subject matter dealt with by the Inquiry, the findings and the methods used to arrive at them are inextricably linked. This paper, however, will focus primarily on the assessment process itself. Facts and findings will be used mainly to illustrate first, the basis for the methodology developed by the Inquiry, and second, the implications of using this approach to acquire sufficient information to make an assessment possible. But before examining the methods employed, a brief look at the circumstances that gave rise to the Inquiry is in order.

BACKGROUND

Canada has long defined itself in terms of its frontiers, seeing them as places to be conquered, settled and developed. We look upon the North as our last frontier. It is natural for us to think of developing it, of subduing the land

and extracting its resources to fuel industry and heat our homes. Our inclination is to think of expanding the industrial machine to the limit of the country's frontiers. In this view, the construction of a pipeline is seen as the next advance in a series of advances intimately bound up with Canadian history.

Investigation of the Mackenzie Valley's potential for hydrocarbon development goes well back into Canadian history. Alexander Mackenzie was the first white man to note oil seepages along the river that now bears his name. And as far back as 1888, a report of a Senate Select Committee noted:

> The evidence submitted to your Committee points to the existence in the Athabasca and Mackenzie Valleys of the most extensive petroleum field in America, if not in the world. The uses of petroleum and consequently the demand for it by all nations are increasing at such a rapid ratio, that it is probable this great petroleum field will assume an enormous value in the near future and will rank among the chief assets comprised in the Crown domain of the Dominion.[3]

In the 1920s, Imperial Oil began developing the oil resources at Norman Wells, and a 4-inch pipeline was built from there to Whitehorse during the Second World War.

Only in the past decade, however, has it seemed likely that this "chief asset," as the Select Committee called it, might at last come into its own. The frontier pipeline and related hydrocarbon development proposals currently being considered result from the 1968 discovery of oil and gas in Prudhoe Bay, Alaska, and Imperial Oil's discovery in 1970 of oil and the subsequent discoveries of gas in the Mackenzie Delta.

Since 1968, the government has responded to these discoveries, to growing public pressure to limit potentially harmful impacts on the physical and human environment, and to the increasingly urgent need to find and exploit new energy resources, by seeking to assess the long-range effects of such frontier oil and gas development.

Thus in 1968, the interdepartmental Task Force on Northern Oil Development was formed to compile information on the existing oil situation in the North and on potential transportation routes; to coordinate all pertinent information available from federal agencies and departments; and to then report and make recommendations to the government.

In 1970, the Government of Canada responded to the northern pipeline proposals being researched by industry by formulating general guidelines for the construction and operation of oil and gas pipelines in the Mackenzie Valley and northern Yukon. These guidelines covered such subjects as environmental protection, pollution control, the corridor concept, Canadian ownership, and the participation, training and employment of northern residents.

In June 1972, "The Expanded Guidelines for Northern Pipelines" were tabled in the House of Commons to provide more specific direction to industry. These dealt only with the corridor concept, the environment, and regional socio-economic matters, and were subsequently to become part of the terms of reference of the Inquiry. The Expanded Guidelines also outlined the information and burden of proof that would be expected in an application to build a pipeline. Essentially the Guidelines required the applicant to demonstrate that its proposed pipeline would be acceptable environmentally and socio-economically.

There is clearly a risk in leaving the exclusive responsibility of demonstrating such acceptability to the party with greatest vested interest. Recognizing this risk - and the fact that adequate data and expertise was lacking - the government established the Environmental-Social Program. The Program, which operated from 1971 to 1975, was to provide baseline data and assessments of the pipeline corridors being considered in the Mackenzie Valley and across the Northern Yukon. Much of the Program's work was of a pioneering nature since there was little environmental, technical sociological data upon which to draw. Total funding for the Program was $17.5 million, and out of it came about 200 reports and papers. Much of this information was subsequently used by the Inquiry.

To fulfil the requirements of the Expanded Guidelines, and prior to filing an application in March 1974, the prospective pipeline applicant, Canadian Arctic Gas, undertook studies on the environmental and socio-economic impact of a pipeline at a cost said to be close to $50 million. The Company also provided $3.5 million to establish the Environment Protect Board (EPB). This group of distinguished scientists and engineers was formed specifically to carry out an <u>independent</u> examination of the pipeline project. They published a series of reports and later appeared at the Inquiry as participants. Their reports and testimony were quite critical of the pipeline proposal; in fact, they found aspects of the project environmentally unacceptable.

In March 1974, Canadian Arctic Gas filed its Mackenzie Valley pipeline application backed by its own multi-million dollar studies and documentation. The application went

simultaneously to two Canadian agencies with overlapping jurisdictional responsibility for assessment and approval.[4]

From the National Energy Board (NEB), with its extra-governmental responsibility for matters of public interest to Canada as a nation, Arctic Gas sought a Certificate of Public Convenience and Necessity. The regular NEB quasi-judicial process was immediately set in motion. Since then, the Board's hearings have moved steadily through the complex national issues of reserves, demand, financing, construction plan, and so on.[5] Its report is expected in July of 1977.

From the Minister of Indian and Northern Affairs, with his responsibility as territorial landlord, Arctic Gas sought a right-of-way permit. The Minister's response was itself twofold: he established the Pipeline Application Assessment Group (PAAG) and the Mackenzie Valley Pipeline Inquiry.

The in-house Pipeline Application Assessment Group, established in early 1974, was composed of sociologists, economists, engineers and environmental scientists drawn from departments of the federal and territorial governments assisted from time to time by outside experts as needed. After a preliminary assessment of the application, it prepared 56 questions that related directly to the requirements of the Expanded Pipeline Guidelines, but that were inadequately dealt with in the application. It then compiled its assessment report -- the first such report produced by government experts following receipt of the Arctic Gas application. This document, The Mackenzie Valley Pipeline Assessment, was published in November 1974, and dealt with the potential socio-economic, environmental, and technical effects of the proposed line. It drew heavily on the research compiled by the Environmental-Social Program as well as from other government, industry and academic research available at the time.

The introduction to the PAAG report commented on two noteworthy aspects of the problem of acquiring adequate information to make an assessment. The first noted that, despite the considerable amount of information available, there are:

> ...some gaps in information. Although many of these involve specific effects of specifications proposed by the applicant, others arise from gaps in basic scientific knowledge.[7]

The second, which refers to Arctic Gas's tendency to give assurances in lieu of hard data, noted:

> The application provides principles and theory but in many respects lacks specifics of the modus operandi; it contains frequent assurances that the subject being considered is adequately understood, that designs will be developed to cope with situations of concern, or that additional studies already planned will remove any uncertainties. [8] (emphasis added)

Both these inadequacies -- the lack of scientific knowledge and of the specifics of the company's intended course of action -- plagued not only the PAAG, but also the Inquiry. It was not until well into the Inquiry's hearings, for instance, that it became apparent that the critical problem of frost heave was nowhere near solution. This example demonstrates one of the difficulties inherent in attempting to assess projects of this scale and complexity. On smaller scale ventures, the "bugs" usually manifest themselves during trial runs, through commercial competition, or because the technology involved is widely enough understood to elicit informed criticism from diverse quarters. But in most huge technological projects, such as the Mackenzie Valley pipeline, there can be no trial runs - problems, even failures, are demonstrable only when the entire system is in place; nor is there likely to be commercial competition; and the only people with the technical knowledge to evaluate the project are its proponents -- who are all the more likely to err precisely because of their own vested interest and the lack of independent criticism.

In many ways this particular project has had the unique advantage of having a second applicant, Foothills Pipe Lines, enter into the foray. The adversary position of the two companies meant that there was criticism available from the industry itself. As a result more technical information became available than would probably otherwise have been the case.

Technical data, however, was only one of the types of information required by the Inquiry. If it -- and gaps in it -- loomed large at the outset, this was because the technological aspects of the project were the foremost concern of the applicant. Naturally, the initial response to the proposal focussed on the same aspects. The Inquiry, in contrast, focused on broader issues. Its concern with technological aspects centered primarily on their involvement with the regional, social, environmental and economic spheres of life. In examining these broad spheres of life, the Inquiry sought to get beyond this or that isolated fact and to comprehensively assess the full impact of the pipeline on the North -- that is to examine the roots of the matter. That this aim was in large measure achieved

was due to the procedures employed throughout the assessment process.

On the day the application was received, the extra-governmental Mackenzie Valley Pipeline Inquiry was established by an Order-in-Council to:

> inquire into and report upon the terms and conditions that should be imposed in respect of any right-of-way that might be granted across Crown Lands for the purposes of the proposed Mackenzie Valley pipeline having regard to (a) the social, environmental and economic impact regionally, of construction, operation and subsequent abandonment of the proposed pipeline in the Yukon and the Northwest Territories, and (b) any proposals to meet the specific environmental and social concerns set out in the Expanded Guidelines for Northern Pipelines...[6]

The scope of the Inquiry was thereby defined both by this Order-in-Council itself and by the Expanded Pipeline Guidelines. The latter proved to be a significant inclusion for, as may be recalled, they dealt not only with the construction of a gas pipeline, but with the development of a Mackenzie Valley corridor -- a far more complex and wide-ranging subject area for impact assessment.

PROCEEDING WITH THE INQUIRY

The Inquiry did not start out with a prescribed set of procedures or a preconceived notion of what would transpire. Its form and content were established on the basis of testimony heard during the preliminary hearings. What it did have from the outset was a broad mandate to see what could be done to protect the people, the environment and the econony of the North. There was, therefore, an obligation to examine fully every conceivable way in which the pipeline might affect the North. Only through a thorough and balanced assessment could the sensitive areas be detected and examined.

That the region has a fragile ecosystem and supports a population that is directly dependent on the environment was, of course, well known. It was also known that the scale and complexity of the pipeline project would place enormous stress on every aspect of life in the region. But because the project itself had no precedent, there was no way of knowing how much of that stress could be absorbed, or which aspects could best or

least absorb it. Consequently, there was no way of knowing in advance what information would prove relevant and what immaterial. Only by considering all information that could or might be pertinent was it possible for the Inquiry to eventually gauge its relative significance.

This meant that the procedures employed by the Inquiry had to be sufficiently flexible to incorporate unexpected departures, to respond to findings as they emerged, and to proceed on the basis of what previously had been revealed. In order for such a learning process to occur, a forum for discussion was provided that was more than merely public, it was accessible and inviting to the people whose interests were being so thoroughly scrutinized.

The Preliminary Hearings: Setting it all up

Thus, to the extent that there were any preconceptions about how the Inquiry should proceed, they lay in the direction of ensuring that it be thorough, fair, flexible and accessible. This was quite outspokenly the view brought to the Preliminary Hearings, but it was not then clear what influence they would have later on, or how they might be incorporated into formalized proceedings.

The function of the preliminary hearings was to allow everyone -- Justice Berger, his staff, Commission Counsel, the applicants, and whoever wished to attend or make a presentation -- to get an overview of the situation. All those who would be affected by the project -- or even remotely suspected they might be -- were given an opportunity to explain their concerns, and to make suggestions as to how the hearings ought to be conducted and what areas the Inquiry should consider.

From what was said during these hearings there emerged the framework for the remainder of the Inquiry: the topics and issues, the ground rules and procedures. It became apparent that if the Inquiry were to fulfil its mandate, it would have to continue to do its utmost to be thorough, fair, flexible and accessible. So ultimately, the view brought to the preliminary hearings became the foundation of the Inquiry's procedures.

The Hearings: Fair and Flexible

The Inquiry hearings themselves were conducted in two different but equally important ways. Between the two kinds of hearings, formal and community, evidence was heard from everyone who wished to participate - from the teenager in Old Crow, the hunter in Fort Franklin, the President of Arctic Gas in

Yellowknife, the fisherman in British Columbia, the MP in Ottawa, and the church groups in Halifax.

In the formal hearings, expert witnesses for each participant gave prepared testimony and were cross-examined by all other participants. It was incumbent upon witnesses to explain not only their position, but the background studies and material from which it was derived. Although formal, these hearings were intentionally not formidable. Most participants were represented by legal counsel, but some participated without such assistance. The Environment Protection Board, for example, was represented by its chairman, an engineer; the NWT Association of Municipalities, by its executive director, and the NWT Chamber of Commerce, by its president.

The community hearings were probably the most publicized aspect of the Inquiry. Although conducted informally, the evidence presented was accorded the same respect and consideration as that presented at the formal hearings. The community hearings were a product of the strongly-urged suggestion put forward during the preliminary hearings that rather than have the people of the North travel great distances to present their concerns, the Inquiry should go to them. And so it did. In 35 communities, over a 6-month period, nearly one thousand people surrounded by their families and neighbours spoke directly to the Judge on every aspect of the project's likely impact. As discussed at greater length in the next section, these hearings provided a forum for testimony of a kind that could not have emerged from their formal counterparts. As the Judge put it:

> We have tried in this way to have the best experience of both worlds, the world of everyday where most witnesses spend their lives, and the world of the professionals, the specialists, and the academics.[9]

Linking the formal and community hearings together and the community hearings with each other was the radio. Each evening when the Inquiry was in session, the CBC northern network broadcast Inquiry news in English and the native languages. Everyone in the region was kept informed and people knew, before the Inquiry arrived in their community, which issues had been debated by the experts and what views had been expressed by their neighbours in other communities.

Radio coverage was not the only means used to make the Inquiry's proceedings accessible. To ensure that there would be a free exchange of all pertinent information, every participant, and the government, provided a list of all their relevant

documents including those that might be privileged. As might be expected, the pipeline applicants had great advantages of expertise and financing over all the other participants. To help balance the situation funding was provided to numerous Native and regional organizations to cover various costs of participation.

In essence, the Inquiry was a learning process for everyone involved. And through the use of the media, distribution of information and the funding of participants, as well as by taking the Inquiry directly into the communities, the Inquiry became one without walls, a truly public forum open not only to the Mackenzie Valley and its inhabitants, but to the cities of the South.

Before looking at the Inquiry in action, there is one final procedural aspect that deserves mention. Early in the Inquiry, all the participants, including Commission Counsel, were asked to prepare arguments in support of the socio-economic and environmental terms and conditions they felt should be attached to granting a pipeline right-of-way permit. These arguments were to be presented in public at the end of the hearings. Asking Commission Counsel to prepare such a document was a novel departure in the history of Canadian inquiries and commissions. In making such a request the Judge felt that all views, including those of his staff, should be made public and everyone should have a chance to rebut them in public. It was a logical extension of the full and fair Inquiry principle that prevailed throughout.

INQUIRY IN ACTION

Once the hearings began, the consequences of the way the Inquiry had been set up gradually revealed themselves. It became apparent that something unique was taking place. Perhaps the most strikingly innovative elements of this Inquiry were the two kinds of hearings each taking place in a different forum. Both the formal and community hearings were designed to gather information, and indeed they did. It was known that the two would vary widely from one another in tone and in the perceptions of the witnesses; that was the intention. What was far from obvious was the extent to which the two would alternately supplement, complement, re-inforce and negate each other, providing at all times a very thorough, well-rounded perspective of the issues at hand. All the participants, no matter how antagonistic their feelings and positions, were able to work together, to learn from one another and to communicate with one another. The attitudes brought to the Inquiry -- thoroughness, fairness, flexibility and accessibility -- were demonstrably coming out of the Inquiry as well.

The Inquiry's mandate, it will be recalled, was to assess the impacts of the proposed pipeline project and of the subsequent transportation corridor that might include amongst other things, an oil pipeline, a highway, a railroad, and electrical power transmission and telecommunication facilities The Inquiry itself sought from the beginning to assess the impact of exploration and development that would follow approval of a pipeline, that is, the cumulative effects of increased activity that would be triggered by the pipeline.

Despite the specific requirements of the Expanded Pipeline Guidelines, an examination of the environmental and social impact of a subsequent oil pipeline in the same corridor as the gas pipeline was somewhat lacking in the pipeline companies' submissions. Needless to say, the cumulative effects of still further development were also lacking. This was, in some respects, quite understandable. It simply was not a concern of theirs. It did not affect their "interests"; they had, after all, assessed the direct impact of the gas pipeline. Why should they bother with the consequences that might follow later?

For local residents, however, the cumulative aspect of development is of the utmost concern. They know full well that a process, once started, seems always to push forward -- first by small increments, then by large ones -- and that the end result is never what was originally intended. Here is one commentary on the subject by Vince Steen, an Inuit resident of Tuktoyaktuk who spoke at the community hearings:

> After them, after the white trappers and the fur traders we have...the government people coming in and making settlements all over, and telling the people what to do, what is best for them, live there, that place is no more good for you. Right here is your school.
>
> So they did, they all moved into the settlements and for the 1950s and 1960s they damn near starved, most of them were on rations because they were not going out in the country anymore. Their kids had to go to school.
>
> Then came the oil companies. First the seismographic outfits and like the Eskimo did for the last 50 or 60 years, he sat back and watched them. Couldn't do anything about it anyway, and he watched them plough up their land in the summertime, plough up their traps

> in the wintertime. What you going to do about it? That cat is bigger than your skidoo or your dog team, you know.
>
> Then the oil companies. Well, the oil companies, I must say, of all of them so far that I've mentioned, seem to...have the most respect for the people and their ways; but it is too late. The people won't take a white man's word at face value anymore because you fooled them too many times. You took everything they had and you gave them nothing. You took all the fur, took all the whales, killed all the polar bear with aircraft and everything, and put a quota on top of that so we can't have polar bear when we feel like it anymore....
>
> Now they want to drill out there. Now they want to build a pipeline, and they say they're not going to hurt the country while they do it. They're going to let the Eskimo live his way, but he can't because... the white man has not only gotten so that he's taken over, taken everything out of the country and everything, but he's also taken the culture, half of it anyway.
>
> For the Eskimo to believe now that the white man is not going to do any damage out there with his oil drilling and his oil wells is just about impossible because...he hasn't proven himself worthy of being believed any more.[10]

Sometimes the expression of concern voiced in the hearings seemed to get through surprisingly fast. Shortly after a verbal attack in Fort Good Hope that was far more vehement than the one above, Bob Blair, the President of Foothills Pipe Lines said to the people of Fort Good Hope:

> Chief T'Seleie, yesterday you connected my name with those of some people who are not my heroes either, including General Custer. I intend to finish my own working life with better success than he finished his, as he well deserved, and I trust from the good spokesmanship and organization I have seen here, that you and the leaders of your people

will finish yours with much greater success than did many leaders at that time too.

I do wish you to know that having heard the things that you said to me yesterday, and which were repeated on the radio, that I have not felt to take them personally, because we have not been acquainted before, but to take them mainly as expressing your very great concern and anxiety, and in some cases suspicion, of the possibility of the pipeline, and to tell you that I understand much, much better from this visit and from being allowed to attend this Inquiry, I understand your concerns much more than I did in the past, and I regard them as serious and important as they deserve.

...There is one other thing we wish to say before the Inquiry leaves Good Hope. I have now asked the Foothills survey teams to hold up any more surveying or testing on the route on the map which comes so close to Good Hope. We want to look at other places for this part of the route and for the wharves.

This means we will hold up using that land use permit, for soil sampling at the Hare Indian River, spoken of yesterday. And we will be ready to discuss with the council the places for a pipeline and river crossing and wharves, which would bother the people here less if a natural gas pipeline is needed in the future.[11]

Expression of divergent views surfaced over and over during the hearings. The experience was not always a pleasant one. As Judge Berger remarked, hard things were said:

> about the government, the pipeline companies, the oil and gas industry, and the white man. But it is better to know how they really feel and to know what they really think, than to encourage them to suppress all differences, and to pretend there are no divisions. If we don't know what is really in their minds, what their attitudes are towards industrial development, we will have no way of knowing what the impact of a pipeline and a

> transportation corridor will be on the peoples of the North.[12]

Obviously the basis for an impact assessment was being forged out of the debates, dialogues and exchanges that occurred. But something else was happening at the same time, possibly for the first time: the pluralistic barrage of opinions and criticisms, to which scientists and technologists have always been quite profitably exposed within the confines of their own institutions or peer groups, was suddenly emerging from an entirely new and external source. A means by which to evaluate the impact not only of the project, but of others of a similar scale, began to develop.

The conventional wisdom that says that only people with special knowledge should make decisions about technological matters was constantly challenged in the hearings and consistently found wanting. Input from non-technical people played a key role in the Inquiry's deliberations over even the most highly technical and specialized scientific and engineering subjects. For example, in volume one of his report, the Judge discusses the biological vulnerability of the Beaufort Sea and relies not only on the evidence of the highly-trained biological experts who testified at the formal hearings, but also on the views of the Inuit hunters who spoke at the community hearings. The same is true of sea-bed ice scour, and of oil spills -- both complex technical subjects that nonetheless were greatly enriched by testimony from people who live in the region. To the experts' discussions of problems and solutions they were able to add comprehensive and vivid descriptions of the meaning of an issue in their daily lives. Their perceptions provided precisely the kind of information necessary to make an impact assessment.

When discussion turned to matters that were non-technological, but still technical -- the complex socio-economic issues of social and cultural impact, land claims, local business involvement, etc. -- it became apparent that the people who live their lives with the issues are in every sense the experts. For example, the land use and occupancy evidence that is crucial to the issue of native people's land claims was compiled and presented to the Judge at the formal hearings in prepared testimony with map exhibits. The evidence was scrutinized and cross-examined by counsel for all participants. At the community hearings, people spoke at length of their traditional and present day use of the land and its resources. Their testimony was often painstakingly detailed and personal. It was spontaneously illustrated with tragic and humorous anecdotes. The transcripts of this evidence are in themselves a major contribution to Canadian history and culture. And it was this testimony that drove home the essence of the claims issues.

Thus the Inquiry was able to link together the myriad of issues surrounding a particular subject. It became increasingly obvious that the whole issue of impact assessment was much greater than the sum of its constituent parts. For example, when North America's most renowned caribou biologists spoke before the Inquiry, they described the life cycle, habitat dependencies, migrations and a host of details about the Porcupine caribou herd. Engineers spoke of the disturbance posed by pipeline construction and operation. Expert evidence was also heard from anthropologists, sociologists and geographers, each of whom spoke of the native people's dependency on caribou from an entirely different perspective. Doctors testified to the nutritional value of country food such as the caribou, and to the consequences of a change in diet. And, of course, at the community hearings the native people themselves spoke of the caribou herd as their link with the past, its role in their culture, its necessity as a present day source of food and clothing, and its value as security for the future. Only in this way, through the input of all people, could the whole picture be put together. And only in this way could a rational impact assessment be made.

The methodology used in the Inquiry meant that information that would not otherwise have been provided surfaced regularly. The contributions of layman and expert together made it clear that an expert is a layman in every field but his own, and the greater the degree of specialization, the more limited is the area of expertise. This unique blending of expert evidence with the thoughts of the ordinary citizen are the hallmark of the Berger Inquiry process and the Judge's report. It is also the key to the thoroughness of the Inquiry assessment and its value as a learning process.

IMPLICATIONS

Had the Inquiry proceeded differently, the whole picture might never have emerged. It was clear from the beginning that the government and the industry had done a substantial amount of homework. Much of the work was an unprecedented and outstanding contribution to Canadian science and technology. Within the terms of reference of the work that was done, the effort was commendably thorough. The few gaps in information in each particular area that did appear during the assessment process are understandable even though some like frost heave may prove to be critical.

However, although millions of dollars has been spent and tens of thousands of pages of backup material assembled, it is now evident that neither government nor industry grasped the

essence of the whole -- the sum of all the issues involved and studies undertaken. It now seems as if there was a belief that if enough studies were done, if enough paper documentation were presented, somehow all would be well and the project could proceed as originally planned. It was a belief that implied the choice; a choice so thoroughly expected that many people in industry, government and the population at large are now bewildered at the findings of the Inquiry and its recommendations.

In attempting to grasp the whole picture, the Inquiry pulled each issue up by its roots and examined it against the backdrop of all the other issues. The results were then assembled into the comprehensive collage that emerged as the Judge's report. This process was inextricably linked to the findings.

Throughout the Inquiry, for example, the pipeline was viewed in the context of the transportation corridor and the cascading effect it would have on a host of other ventures. From this perspective it became clear that in certain places, such as the northern Yukon and the mouth of the Mackenzie Delta, no pipeline should be built and no corridor should be established because of the threat posed to whole populations of birds, caribou and white whales. In the Mackenzie Delta and Beaufort Sea, the report highlighted the dangers of proceeding with full-scale hydrocarbon development without satisfactory technology to clean up oil spills. The Judge's report also concludes that there was no environmental impediment to a pipeline and a corridor in the Mackenzie Valley, but construction should proceed only after settlement of the native land claims issue.

The desire of native people for self-determination through the resolution of their land claims was the overpowering message conveyed to the Inquiry through the community hearings, and is the subject of much attention in the Judge's report. This is one issue where all the background studies from both industry and government were very vague. This may be due to the highly sensitive political and legal issues involved; but to ignore them when assessing pipeline impact would have been evasion of responsibility of the most serious nature. The Inquiry was really the only vehicle capable of tackling this issue - one that was wholeheartedly endorsed by the native people themselves.

These few examples show how the Inquiry became a "full picture" learning process, how its assessment process linked the more tangible technical and environmental issues with the gut wrenching exposure of very personalized social and cultural concerns. Many hard things were said but the very fact that they were said illustrates the faith that the people placed in the

Inquiry's process. As a process, it reached out beyond the direct participants: it became one in which all Canadians north and south participated. It touched some of Canada's deepest concerns -- concerns about energy policy, resource allocation, the price and priority of industrial development, cultural sovereignty and self-definition. We really did, as Mayor Sykes said, pull ourselves up by the roots.

In many ways, this has led to a better understanding of our country and clarified some essential details of what Canada really is. It has been a process in which the south has learned about the north both as a frontier and a homeland.

In response to the interest generated in the South, the Inquiry visited ten southern cities from Vancouver to Halifax in May and June of 1976. At the end of those hearings the Judge said:

> I have tried to learn something from each one of you, and I hope you have tried to learn something from each other.
>
> It should come as no surprise that on each side opinions are strongly held, touching as they do many of our nation's deepest concerns about the development of the North, the environment, patterns of energy consumption, and the rights of native people.
>
> We have had a confrontation of principles, of ideas and of theories at these hearings. That is a good thing I believe, as long as we are prepared to listen to one another, to consider the opinions not only of those with whom we agree, but also of those with whom we disagree.
>
> Out of this debate we can seek to establish constructive approaches to northern development to recommend to the Government of Canada....
>
> The submissions of these hearings have been constructive and creative. The debate for this last month has been worthwhile, if Canadians now have a greater awareness of the issues facing the North and all of us than they did before.

> Certainly, the country has shown a very great interest in the hearings. It proves that Canadians are not wired into their T.V. setts, but are willing to come out into the sunshine to discuss these questions that are so important to us all.[13]

As a result of the Inquiry and the Judge's report, Canadians were exposed to a diverse and complex range of development issues. Through that exposure they have begun to recognize that the core issues are southern problems as well as northern ones. Problems of energy, environment and justice to native peoples are national not just regional.

So the Inquiry was -- and is -- a grand encounter session in which the North learned about itself, the South learned about the North, the North learned about the South and the South learned about itself. The fairness of the process became a national mirror for all Canadians to view themselves for what they really are. Both the process and the findings were startling and disturbing to many. And yet it instilled an unprecedented feeling of faith in many others. No matter what the final decision about the pipeline is, the Inquiry will have a profound and lasting national influence.

The Inquiry has shown us a way of acquiring and disseminating information about a highly complex, technological project. This in itself is unusual. Furthermore, it did this while maintaining a human balance, a concern for things non-technological. It has shown how the vital role of the technical expert can be blended with the input of all people who are affected by a venture, directly or undirectly. It shows how to get complex information to and from all people, expert and layman. It really was an example of participatory technology, a way of assessing superstar technology while still maintaining a human perspective.

The Berger Inquiry's methodology reveals the extent to which information is the key element of an assessment process, and that the group that controls the information controls all else. The methodology recognized that the expert has no exclusive right to information. Indeed, it shows that the obligation of the expert, industry and government is to expose at a very early stage the whole range of issues to the "expert" scrutiny of all citizens whose input has been shown to be invaluable.

The understanding and exchange of expertise that occurred during the formal and community hearings exemplifies the strength of the methodolody of what has become popularly known as

a Berger type inquiry. The methodology is no longer dependent on Justice Berger. Already the Feed Paper Inquiry in northern Ontario and the Kitimat Inquiry in northern British Columbia have been described as Berger type inquiries.

There may also be changes in the operation of ongoing regulatory bodies in Canada. These have long been relegated exlusively to lawyers and highly specialized experts to the exclusion of the citizens in who's name decisions are often made in the "national interest".

The process initiated by Berger has been long overdue in Canada. That is not to say that "pulling ourselves up by the roots" has to become a national pastime. Like Confederation it is a necessary starting point, but it does not have to be repeated over and over again. But, clearly this has been a vital, healthy and progressive development affecting all aspects of Canadian life.

FOOTNOTES

1. Mayor R. Sykes
   Community Hearings Transcripts, Mackenzie Valley Pipeline Inquiry, Vol. C-52, p. 5225.

2. Thomas R. Berger
   Northern Frontier Northern Homeland: Report of the Mackenzie Valley Pipeline Inquiry, Vol. I, P. 1.

3. Report of the Select Committee of the Senate appointed to inquire into the resources of the Great Mackenzie Basin, Session of 1888.

4. The international character of the Arctic Gas proposal necessitated their applying to the United States Federal power Commission as well. That Commission's hearings ran concurrent with those of the NEB and the Inquiry. Its report was made public in early May 1977.

5. "Steadily" requires some qualification since there was, infact, a rather major setback after the NEB hearings were well underway owing to a successfil legal challenge by several participants. The panel hearing the application was changed and the hearings started over in April 1976 after it was ascertained that there was a reasonable apprehension of bias on the part of Mr. M. Crowe, one of the original panel members and chairman of the Board.

6. Order-in-Council designating the Honourable Mr. Justice Thomas R. Berger as Commission of the Mackenzie Valley Pipeline Inquiry, under the provisions of the Territorial Lands Act (1-7378B, 21 March, 1974).

7. Canada. DIAND. Pipeline Application Assessment Group
   1974 Mackenzie Valley pipeline assessment. p. 3

8. Canada. DIAND. Pipeline Application Assessment Group. op. cit. p. 5.

9. Thomas R. Berger
   The Mackenzie Valley Pipeline Inquiry, Queen's Quarterly, Vol. 83, Number 1, Spring 1976. Reprint, p. 8.

10. Vince Steen
    Community Hearings Transcripts, Mackenzie Valley Pipeline Inquiry, Vol. c-44, pp. 4200-4202.

11. Robert Blair
Community Hearings Transcripts, Mackenzie Valley Pipeline Inquiry, Vol. c-19, pp. 1849 and Vol. 20,pp. 1909.

12. Thomas R. Berger
The Mackenzie Valley Pipeline Inquiry, op. cit. p. 9.

13. Thomas R. Berger
Community Hearing Transcripts, Mackenzie Valley Pipeline Inquiry, Vol. V67, pp 7820.

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THE ROLE OF ENVIRONMENTAL ASSESSMENT IN A MAJOR PULPMILL EXPANSION PROGRAM

C. F. GORHAM

BACKGROUND

In July 1974 Kimberly-Clark of Canada Limited announced plans for a major expansion program to enlarge its bleached softwood kraft pulpmill at Terrace Bay, and to expand its regional woodlands operations. Cost of this program is expected to be $240,000,000, and upon completion in late 1977 production capacity at Terrace Bay will be increased from the present 425 tons/day to 1,250 tons/day.

To support the expanded production facilities at the Terrace Bay mill, the Company has been granted Crown Timber Licenses to harvest a combined area of more than 12,000 square miles in the Districts of Cochrane and Thunder Bay in Northwestern Ontario.

PRESENT OPERATIONS

The Pulp and Forest Products Division of Kimberly-Clark of Canada Limited presently operates a 430 A.D. tons/day (390 metric tonnes/day) bleached kraft pulpmill, 35 million board feet/year studmill at Terrace Bay, and a 40 million board feet/year lumber mill at Longlac, Ontario. Wood to supply these current operations is harvested by the Company from a 7,300 square mile timber limit operated under license from the Ontario Government.

The present total annual cut is 450,000 cords and woodlands manpower number 630. Headquarters for the Company's woodlands operations is Longlac, a town of 1,700 located on Long Lake about 90 miles north of Terrace Bay.

Kimberly-Clark has pioneered the "commuter" approach to logging, whereby woodland's workers are transported by Company buses to the cutting areas on a daily basis. As a result, employees make their permanent homes in a number of communities located throughout the timber limits. The major home bases are in Longlac, Geraldton, Nakina, Schreiber and Terrace Bay. The advantages to the worker living at home as opposed to "live-in" camps are obvious. There are also significant benefits to the Company, particularly in the form of a stable reliable work force.

Wood is delivered to the Terrace Bay pulpmill by both water, as 8 foot logs, and by road in tree length form. The water delivery system includes a rafting operation on Long Lake, followed by the natural flow of logs down the Aguasabon River and diversion canals to Terrace Bay. Land delivery, comprising 60% of the wood supply, is by trailer trucks along the Company's private road system.

The present pulpmill at Terrace Bay is a conventional kraft pulpmill operation producing 148,000 tons/year (134,000 metric tonnes) of fully bleached northern softwood kraft pulp. The mill was constructed in 1947-48 and although there have been significant production increases since mill start-up, there have been relatively few major capital projects in the mill's 30 year history.

Since the initial mill start-up, the Company has operated an external treatment system for mill effluent, making use of natural lagoons and

canals before discharge of effluent into Lake Superior at Moberly Bay. This system has provided excellent control of suspended solids, but has been less effective in reducing Biochemical Oxygen Demand. The Company, as part of its routine effluent audit program, has carried out regular Benthic surveys at the point of discharge in Lake Superior. These surveys have shown a gradual, but continuing, deterioration of conditions adjacent to the point of discharge.

Employment at the Terrace Bay pulpmill and adjoining studmill numbers 500. Most of the work force lives in Terrace Bay, although there are a significant number of employees who make their homes in Schreiber, a town of 2,000 population located 9 miles west of Terrace Bay.

SCOPE OF EXPANSION DEVELOPMENT

At a meeting of the Kimberly-Clark Board of Directors in Terrace Bay in July 1974, the Corporation approved in principle, plans for a $240 million program to enlarge the kraft mill at Terrace Bay and expand the woodlands operations. The program, which would result in a tripling of pulping capacity at Terrace Bay, was to take place over a three year period with start-up of the new facilities planned for late 1977.

The enlarged kraft mill will provide employment for an additional 150 people, while the expanded woodlands operation will add a further 525 new jobs. Most of the new employees for the expanded mill are expected to live in Terrace Bay. However, the additional employees required for the wood-

lands operation, will reside in a number of communities located throughout the timber limits.

In addition to the permanent increase in work force, the construction phase of the program was expected to require an excess of 1,200 people on the mill site during the peak construction period.

The expected large influx of people to a number of small communities, the temporary requirements for a large transient construction force, the significant increase in logging operations and the extensive requirements for effluent control for the expanded mill operations -- all pointed to the need for a comprehensive evaluation of the total environmental impact of the Company's expansion program.

ENVIRONMENTAL ASSESSMENT

Prior to the formal announcement of its expansion plans in July 1974, the Company had been carrying out preliminary studies on environmental control as part of the process design for the projected expanded mill operation. Beak Consultants Limited were retained to assist in the development of a comprehensive environmental protection program which was being prepared for review with the Ministry of Environment as a prerequisite in obtaining program approval from the Ministry for the expanded pulpmill. At about the same time, the Ontario Government was enacting legislation requiring formal Environmental Assessment under certain conditions. Although the Act did not, at that time, apply to most undertakings in the private sector,

there was naturally a certain amount of discussion between representatives of Ministry of the Environment and Kimberly-Clark on the potential value of Environmental Assessment. It was apparent at a very early stage in the development of Kimberly-Clark's expansion plans that interactions with various government agencies, with municipalities who would be called upon to supply services for new residents and, with the public at large, would be many and varied. It seemed that the ideal method of identifying potential problems, and of providing complete information to the public and government agencies, would be through a rigorous and systematic environmental assessment, such as would be required for a project under the Environmental Assessment Act. Consequently, in May 1974, prior to the public announcement of the expansion program, Beak Consultants Limited were instructed to carry out a complete Environmental Assessment of the Kimberly-Clark development and to prepare an Environmental Assessment Report for distribution by Kimberly-Clark to the various interested agencies of the government and the public.

ENVIRONMENTAL ASSESSMENT REPORT FORMAT

Once the decision had been made to carry out a voluntary Environmental Assessment a meeting was arranged with the Ministry of Environment to review guidelines for the content of the report. Although the major contact with the Ontario Government on Environmental Assessment has been through the Ministry of Environment, other Ministries, including Natural Resources, were included in the development of the Assessment Report form.

The final format established for the Environmental Assessment Report comprised six major sections: 1. A description of the proposed development; 2. A description of the pre-development environmental setting; 3. An analysis of the impact of the development on the natural, social, cultural and economic environments; 4. A description of the measures to mitigate adverse environmental effects; 5. An analysis of possible alternatives to the proposed project; 6. And finally, a summary of the environmental impacts and a regional perspective on the effects of the development.

The Environmental Assessment was intended to be a comprehensive analysis of all the potentially significant effects the project would have on the environment. Our objective was to prepare a fair assessment of the development, based on scientific analysis. At the same time, we wanted the Report to be readable and understandable by the layman, who in the end would be most affected by the results. In preparing the Report, we have attempted to maintain a balance between detail and scope.

CONTENT OF THE ENVIRONMENTAL ASSESSMENT REPORT

The Assessment Report is, of necessity a fairly lengthy document. Certainly, it would not be practical for me to offer a complete review of its contents. Never the less, I would like to discuss briefly each section of the Report to illustrate the methods and level of detail used in its preparation.

1. Description of Proposed Project

In the first section of the Environmental Assessment Report a complete description of the Company's current operations is given. The logging operations, centred in Longlac, are discussed and the increase in timber required to support the expanded facilities is identified. The Report points out that in addition to the present delivery system utilizing a river drive and truck delivery of tree length wood, rail delivery of 8' wood from the northern timber limits will take place from a new slasher to be located near Nakina.

This section of the Report also includes a process description of the existing mill, and a brief description of the new facilities.

The effluent systems for the present and expanded mill conditions are discussed, but with limited reference to their effects on the environment, since this is more fully covered in a subsequent section of this Report.

This section of the Environmental Assessment Report also contains a preliminary construction schedule and anticipated start-up date.

2. Pre-Development Environmental Setting

The second section of the Report contains a reasonably detailed description of the pre-development environmental setting, including both the natural environment of the surrounding area and the social, cultural and economic environments of the communities in the timber limits.

A brief review of the bedrock and surface geology is given, using well-established data but with a minimum of field surveys. A general description of the topography is included, but again, the information is provided for background discussion and is not detailed.

Considerably more attention is given to other ecological features. For example, since mill effluent will continue to enter Moberly Bay on Lake Superior a detailed description of the present condition of Moberly Bay and Jackfish Bay, of which Moberly Bay is a part, is given. Because the mill has been using this water course for the disposal of effluents since mill start-up, a significant amount of background information was available. A number of biological surveys have been carried out by the Company over the past 15 years and these surveys provided information on the benthic substrates. In addition to the investigations carried out by Kimberly-Clark, the Ontario Government has also done a number of water quality surveys of Moberly and Jackfish Bays. This data is also included.

No detailed studies of the fish ecology of Moberly or Jackfish Bays were carried out as part of the Environmental Assessment, but some previous information was available and was included in the Report.

Although five commercial fishing licenses are being administered by the Ministry of Natural Resources in Terrace Bay only one fisherman occasionally fishes the Moberly Bay - Jackfish Bay area.

However, shallow, near-shore waters such as Moberly Bay are recognized as being important to fish reproduction. Consequently the Report notes that this area has significance beyond its commercial fishing potential.

A second important aguatic system discussed in the Assessment was the Long Lake - Aguasabon River system. This waterway delivers a significant percentage of wood from the Company's woodlands operations in the Longlac area to the mill in Terrace Bay, 90 miles to the south.

Although Long Lake was not extensively studied, it was surveyed by the Ministry of Natural Resources in 1968 and 1969. A summary of these surveys is included in the Report. An interesting situation exists on Long Lake in that the water level is controlled by Ontario Hydro, by manipulating dams at the north and south ends of the lake. Drainage can be directed either north through the Kenogami River to Hudson Bay or south via the Aguasabon River to Lake Superior.

The Assessment Report includes comments on the possible effect of bark in Long Lake. The lake has been used by the Company for rafting wood to the Aguasabon River since mill operations began almost 30 years ago. The Report warns that a build-up of bark could contribute to covering of spawning beds for Lake Trout.

However, the Report goes on to note that the occurrence of oxygen levels of 9ppm at a depth of 400 feet and the presence of pollution-sensitive fish species suggest little alteration in the lake ecology to date.

The third major aguatic system within the project's development area are inland lakes and rivers. The major drainage systems throughout the area are described in the Assessment Report and the extent of tourism and sports fishing, which is not major but still significant, is outlined. Generally, the streams and lakes throughout the area are considered to be in good condition and to have suffered relatively little environmental damage as a result of operations to date.

The Assessment Report contains a description of the terrestrial ecology, including the type and predominance of the wood species. Animal life throughout the expanded timber limits is discussed with the majority of the information coming from reports and communications from the Ministry of Natural Resources. Since this area receives moderate pressure from hunters, the significance of moose hunting is discussed.

A wide variety of fur bearing animals inhabit the timber limits, but the Report notes that trapping activity is relatively light. The Report goes on to discuss the occurrence of other wildlife, including water fowl and game birds.

The Assessment Report includes a review of climatic conditions and growing season in the project area, drawing information from weather reporting stations in towns within the timber limits.

The development of the Kimberly-Clark expanded mill and woodlands operations was expected to have a major impact on the communities of Terrace

Bay, Schreiber, Longlac, Geraldton and Nakina, which are within the area of Company operations. The section of the Assessment Report describing the pre-development environmental setting reviews in some detail, the social, cultural and economic environments of these towns. The origin and growth of the communities is discussed and the labour force and major sources of employment are listed. The ethnic background of residents is given, along with an assessment of second language facilities. Availability of schools, including secondary and trades or occupational training facilities, is described. The impact of the present Kimberly-Clark operation in each town is discussed, including the Company's effect on per capita income and municipal taxation. Zoning regulations in effect in each town are identified, particularly as they apply to urban development.

Housing within the towns is reviewed along with the availability of serviced land. Commercial areas are described and an assessment made of the availability of shopping and recreational facilities.

Access to the towns by public transportation is reviewed and communication facilities available to each of the towns is assessed.

The availability of medical facilities is examined, including dental and ambulance services.

Police and fire protection facilities in each town are described along with the availability of legal counselling.

The Report shows that there are marked differences in facilities and services available to each town. This is particularly obvious in the case of Nakina and its neighbouring Indian settlement, Aroland, which have very limited capacity for the major population growth predicted by the Report for this area.

The pre-development environmental setting provides the bench mark information on which is based the assessment of impact of the woodlands and mill expansion development.

3. Environmental Impacts of Development

Having established the pre-development setting, the Environmental Assessment goes on to predict the probable impact of the Kimberly-Clark development. The same basic format in reporting potential impact is used in this section of the Report as was used in establishing the pre-development environmental setting. The effect on the natural environment is assessed as well as the predicted effect on the social, cultural and economic environments of the towns in the development area.

The Assessment Report discusses the expected effect of mill effluent at Moberly Bay, which will continue to be the point of discharge of mill effluent to Lake Superior for the expanded operations. Although the mill's production will nearly triple, the net effect of effluent on Moberly Bay is expected to decrease. The expanded mill will be implementing a pollution control program, and the Report predicts that the external facili-

ties along with in-plant controls and the polishing action of the present lagoon system will result in protection, and in fact a gradual improvement in the conditions at Moberly Bay. Although the Assessment Report includes a description of the mill effluent control systems, a more complete discussion is contained in an Environmental Protection Program, issued separately to the Ministry of Environment.

The effect of increased logging activity on the Long Lake - Aguasabon River system was difficult to assess. Water transport of wood can be expected to result in a number of potential problems on water systems, including the possibility of smothering benthic invertebrate and fish spawning beds with bark, and the reduction of dissolved oxygen levels through decomposition of bark and logs. The Environmental Assessment attempted to quantify these problems and determine impact. It was concluded that if there was a bark problem it would probably occur in the wood holding area near the mill jackladder and a major build-up of bark in the river itself was unlikely.

The Assessment Report noted that the cutting operation over the expanded timber limits would increase from 20,000 acres/year to 45,000 acres/year. All cutting operations will continue to be regulated by the Ministry of Natural Resources through forest management plans, and the overall results of the increased logging activity was not expected to seriously impact on inland lake and river systems. It was predicted that the quality of

forest lands will be enhanced in the long run through the harvesting of mature and over-mature stands, and through the application of a satisfactory reforestation program.

The Assessment Report identified a potential for increased forest fires. This was expected to be particularly true in areas where logging operations would make prime hunting and fishing areas more accessible to the general public. But some off-setting benefits were also identified. For example, as a result of expansion, Kimberly-Clark will have available to the Ministry for forest fire control, a large increase in manpower and equipment. In addition, logging roads built by Kimberly-Clark would provide essential access to fires.

A review of the potential impact of increased logging operations on wildlife within the timber limits indicated little likelihood of change. None of the mammals listed as endangered Canadian species are found within the Kimberly-Clark timber limits. Three species of birds from the endangered species list do breed within the timber limits. However, a review of the environmental requirements of these species indicated that they would not be affected to any significant extent.

The Assessment Report attempted to evaluate the effect of the expanded mill on air quality. Simulation of ground level concentrations of SO_2 T.R.S. and particulates was carried out for the expanded mill conditions and an improvement in these emissions was indicated.

The Report left no doubt that there would be significant social, cultural and economic impacts on the communities within the Company's timber limits. In some of the communities the Kimberly-Clark development was not expected to affect the municipal structure or services. In other municipalities, however, the development was expected to result in population growth that would severely strain and in some cases over-tax existing services.

In Terrace Bay, the additional employment in the expanded mill will increase population by about 850 people, 45% above pre-expansion levels. In addition to a permanent increase in population, more than 1,200 construction workers were expected to be working in Terrace Bay during the peak construction period. Such an influx into a community of under 2,000 people could be expected to result in considerable problems. A severe shortage of housing, both temporary and permanent, and an overloading of town services including educational, recreational, entertainment and shopping facilities was predicted. The Assessment also identified a number of other potential problems in Terrace Bay which would require mitigation.

The town of Geraldton, at 3,000 the largest community in the development area, was expected to increase in population by about 300-400 people due to Kimberly-Clark's expansion. Although this would put a strain on some services, it was not expected that there would be an adverse impact on the social, cultural or economic environment of the town. Beneficial effects of the development would include a stabilization of the population to balance a decline which occurred in the early 1970's.

In the case of Longlac, headquarters for Kimberly-Clark's woodlands operations, expansion will result in an increase of between 350 and 450 in the present population of 1,800. Additional housing will be required for new residents, and the Assessment Report indicated a possible need to expand the water treatment facilities.

Nakina which will become the cutting base for the Company's new timber limits in the north, will experience about 250 new Kimberly-Clark employees moving into the town. This will result in a more than doubling of the present population of about 700, and will require a significant increase in housing and in municipal services, along with a need for improved health care services and better commercial and recreational facilities.

4. Measures to Mitigate Adverse Environmental Effects

The Environmental Assessment process requires a consideration of methods to eliminate or reduce to an acceptable level the adverse environmental effects which become evident during the analysis. Some of these measures were discussed in previous sections, but a major section of the Report is devoted to a review of the actions that will be taken to mitigate adverse environmental effects.

Mill effluent control programs are outlined, along with the Company's plans to protect from environmental damage, the inland aquatic systems and terrestrial ecology of the timber limits.

The major areas of concern, identified earlier in the Environmental Assessment, were the social, cultural and economic impacts resulting from an influx of people into the various communities. Although the responsibility for solutions to many of the problems rests with the various levels of government and their agencies, Kimberly-Clark has initiated a number of projects to assist in mitigating some of the major problems. For example, in Terrace Bay, the Company has assisted in the development of a 340 lot subdivision, has constructed 30 single family homes and 2 apartment buildings.

In addition to providing facilities for mobile home accommodations for married construction workers and their families, the Company constructed a large temporary construction camp on the mill site for about 800 single construction workers. In order to provide as many services as possible on the camp site and to avoid overloading town services, the Company built a complete recreation complex for the exclusive use of construction camp residents. Included in this complex is a library, crafts room, exercise gym, snack bar, cocktail lounge and games room. A full-time recreation director is employed to develop programs for camp residents.

In Longlac, the Company is constructing 2 apartment buildings to assist in the accommodation problem.

In Nakina, Kimberly-Clark has developed an 82 lot subdivision and has completed construction of 11 homes. A further 45 homes are to be completed by the end of 1977, along with a 17 unit apartment building.

The township of Nakina is also planning an additional 100 lot subdivision. To accommodate the growth in the town's population, water and sewer services are being expanded by the municipality.

Potential impact of the Kimberly-Clark development in areas such as schooling and health services are more long range and will require considerable further study by the municipalities and appropriate agencies.

5. Alternatives to the Proposed Project

To complete the Environment Assessment procedure a review of potential alternatives to Kimberly-Clark's development was carried out.

In reviewing the possibility of an alternative mill site for expansion it was obvious that the location of the Company's existing mill, water transportation system and timber limits, as well as the municipal structures of Terrace Bay, Longlac, and other area towns made the present site of the development the only reasonable one.

In the case of timber limits, the current and expanded Kimberly-Clark limits are on the northeastern edge of Ontario's merchantable timber area. All surrounding commercial timber is under license to other companies, eliminating any potential alternatives for wood supply.

6. Summary of Environmental Impacts

The Environmental Assessment Report concludes with a summary of the evitonmental impacts of the Kimberly-Clark development. The summary comments that the ramifications of the proposed development are in line with stated

policies of municipal and provincial agencies concerned with the future of Northwestern Ontario.

The Environmental Assessment process was initiated in May of 1974, and the Report was completed by Beak Consultants in December 1974. Copies of the Report were forwarded to the Ministry of Environment and the Ministry of Treasury, Economics and Intergovernmental Affairs. Copies were also sent to townships within the area and to public libraries.

In order to provide as complete a description as possible of the Company's development plans, Kimberly-Clark organized a number of public meetings, to which, in addition to the general public, representatives of the government were invited to attend. Meeting were held in the spring of 1975 in Terrace Bay, Longlac, Geraldton and Nakina. Using information from the Environmental Assessment Report the Company presented a description of its development program. The meetings were open to general discussion and the Company's environmental and engineering consultants were on hand to assist in any technical questions. These public meetings, which were very well attended, generated considerable discussion, with the major areas of concern being housing and municipal services.

In addition to the public meetings, the Company undertook to publish a regular newsletter outlining expansion progress and describing various aspects of the project in some detail. This newsletter is issued approximately every two months and is sent to all residents in Terrace Bay,

Longlac and Nakina, as well as a general circulation to Schreiber and Geraldton. Copies are also forwarded to various agencies and officials of the Provincial Government and the media.

Kimberly-Clark of Canada feels that the Environmental Assessment process has been a valuable undertaking. It has required a detailed review of the overall development concepts at an early stage and enabled the Company to present its plans to the public in a comprehensive, organized manner. The response from the public to the Environmental Report was positive and constructive and many early concerns about the effect of the expansion program were abated. The municipalities have used the Assessment Report in their discussions with the government on the provision of needed services and we believe the Report has helped to avoid many pitfalls that might have occurred had there been an adhoc approach to the concerns of the various communities.

We have been told that the Environmental Assessment document has been of considerable value to the Provincial Government. The Report has provided an overall description of the development program to all ministries, thus allowing a co-ordinated approach to the solution of many of the potential problems identified in the Assessment. We understand that the Report has been of particular value to the Ministry of Environment.

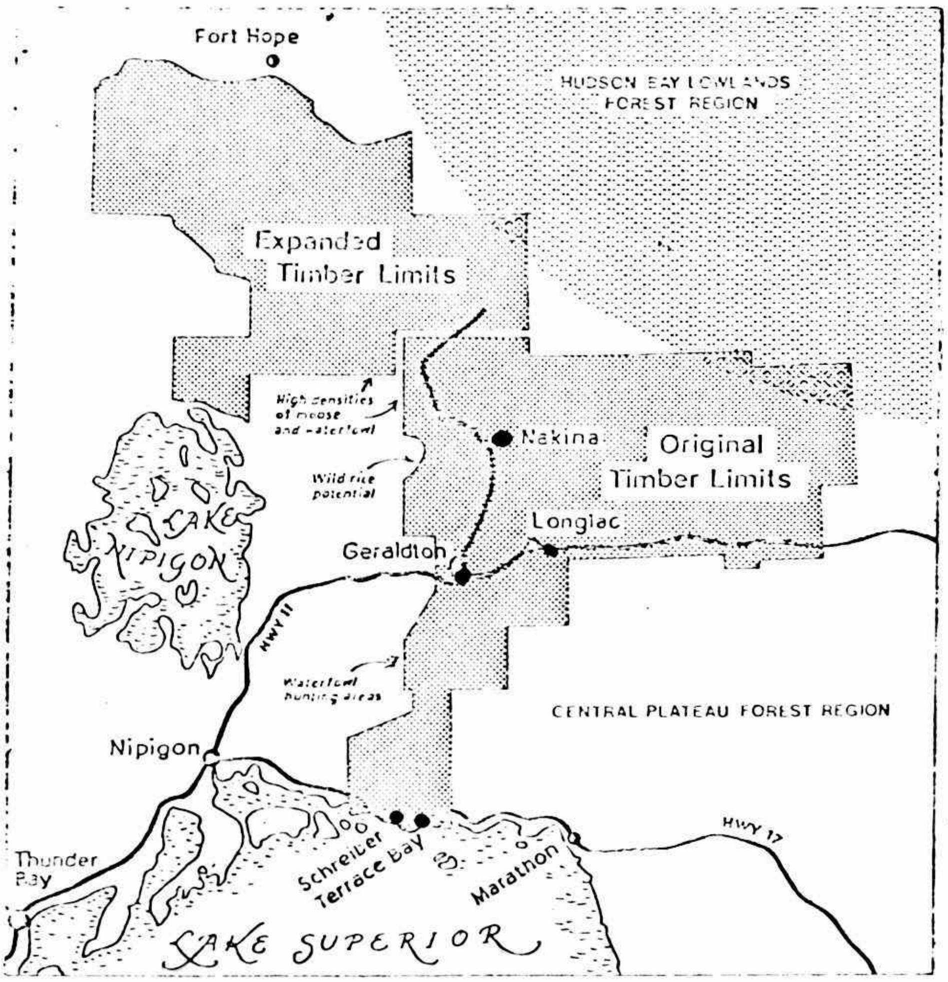
Application of the Environmental Assessment process has provided a basis for rational and objective discussion among the government, the public,

and the Company. The process allowed the orderly and environmentally acceptable development of Kimberly-Clark's expansion program in Northwestern Ontario.

FIGURE 1

KIMBERLY-CLARK OF CANADA LIMITED

TIMBER LIMITS



THE COMMUNITY APPROACH

TO ENVIRONMENTAL APPROVAL

W. J. GRANT, P. ENG.

Introduction

Studies conducted during the early 1970's showed a growing deficiency of lubricating oil refining capacity in Canada which could be made up only by increased imports. These studies also indicated that the Furfural Extraction and Dewaxing Process Units commissioned in 1943 at Gulf's Clarkson Refinery could not be expanded to help meet this deficiency. In addition, these processes require selected domestic crude oils which are becoming more difficult to obtain. The environmental protection built into these units, although upgraded over the years, still falls short of modern standards.

Alternative sites including the no project alternative were evaluated prior to choosing Clarkson Refinery. The new complex will consist of Hydrotreating, Dewaxing, Propane Deasphalting auxiliary tankage plus extensive changes to the compounding and blending facilities. Included will be a new computer controlled warehouse in which lubricating oil products will be stored in thousands of individual storage cubes.

Clarkson Refinery is located on about 400 acres of land about 20 miles west of Toronto on the north-shore of Lake Ontario. Built during wartime on open farm land, the refinery is now bordered on the north by medium-priced homes and apartment complexes, and on the east by high-priced single family residences.

Because of prevailing wind conditions during the summer months, complaints come mainly from the latter area. While large sums of money have been expended over the years, and much progress made in reducing odours and noise, the community remains highly sensitive because of its close proximity to the refinery. Ambient air quality surveys conducted during the last six years by our Research and Development Centre's mobile environmental van show that air quality up to now meets all government requirements. However, there are occasional problems due to short-term emissions of odour and noise caused by plant operating variables. The main effort has been directed towards improvement in these two problem areas.

Environmental Project Team

It was clear from the beginning that a project of the magnitude of an expanded and modernized lubricating oil plant costing $180 million and extending over a two year construction period would raise some concern in the community. The matter was discussed within the Corporate Environmental Affairs Committee which was established in 1966 to oversee the environmental responsibilities of the company. The Committee recommended formation of a special project team to carry out the following:

1. Co-ordinate the flow of information to the community, government regulatory agencies, employees and the outside public.
2. Initiate base-line studies in co-operation with Engineering Department where there was insufficient information.

3. Review these studies for adequacy when completed.
4. Keep the Senior Executive informed of progress.
5. Advise the Engineering Department of any additional funds or changes in design which might be needed to meet environmental requirements.
6. Prepare an environmental assessment report.

The Environmental Project Team was composed of the following personnel:

- Manager of Clarkson Refinery
- Co-ordinator of Process Engineering
- Representative from Project Engineering Department
- Advisor on Environmental Affairs for Refining Department
- Manager of Public Relations Department
- Representative from Research & Development Department

This group was not too large or unwieldy and yet contained people with a good cross-section of needed background and knowledge. Beyond exposure at workshops and seminars, none of the team had been involved previously with the environmental assessment process.

The first step taken by the project team was to arrange for various members of the Senior Executive to talk to the Federal and Provincial Governments in order to acquaint them with the need for this project. Next, the Mayor, Council member and the

Ministry of the Environment were approached to make certain that they understood the nature of the project and the steps which would be taken to look after the environmental aspects during construction and operation of the new facilities.

Environmental Assessment Report

In mid 1975, discussions were held with the Ontario Environment Ministry's Director of Approvals and his staff to get their reaction to the project. While it was clear that the new units could be designed to meet all of the province's regulatory requirements, the Director indicated that the approval process would be facilitated if the company could demonstrate that the project would be acceptable to the community.

The Environmental Assessment Act passed in 1975 did not require the private sector to carry out an environmental assessment. However, in view of the sensitivity of the area and the need to discuss the matter with the community, the company decided to proceed with an environmental assessment.

The Environmental Project Team identified areas which needed in-depth examination and commissioned consultants to make studies and prepare recommendations on the following subjects:

- Changes in traffic levels in and out of the refinery before, during and after construction is completed.

- General appearance of the plant and how it might be improved.
- Opinion of the community regarding Gulf as a neighbour.
- Current noise levels and how they might be reduced even with the proposed new project.
- Changes to the waste water treatment system.
- An air management study focussing on SO_2 control.

Studies conducted on air, water and traffic levels followed the usual course, and concluded that any possible adverse changes could be taken care of by good engineering design. The remaining three areas namely: community concerns, plant appearance and noise control are of major significance and will be discussed in greater depth.

Assessment of Community Concerns

Early in 1975 Contemporary Research Centre was engaged to survey the attitudes and concerns of the people living north and east of the refinery. A particular focus was the relationship between the refinery and the community. It was hoped that these findings would indicate the degree of sensitivity towards the refinery and provide guidance to the project team in deciding on what improvements would gain public acceptance.

In June, 24 specially trained interviewers surveyed 998 out of 1319 households for a response rate of 76%. The people interviewed were first asked a number of general questions about their personal concerns and views on the community. In this way their attitude about the refinery could be put into better perspective.

It came as a surprise to learn that concern about refinery operations ranked only sixth and was preceded by the fear of overcrowding of the area, lack of adequate public transportation, traffic problems, education and inadequate recreational facilities in that order.

Air, water and odours were mentioned by 6-8% of the people living to the north, whereas to the east the concern was about three times as great. Of the 10% concerned about the environment, odour was mentioned by 41%, air and water by 25% and plant appearance by 12%. Noise was a concern only to the community to the east and then only to those people living near the property line.

In response to a question about positive aspects of the refinery, 31% of the respondents rated the employment it provides as the best thing, followed by: the essential products produced for society, community-mindedness displayed, contribution of taxes, and efforts to control pollution. When asked what things might be done to add up to a really outstanding performance, 36% mentioned cleaning up air and water pollution while almost 20% suggested making the plant more attractive.

All of these findings proved useful to the project team in addressing the real concerns of the community.

Improvement in Plant Appearance

As a result of the opinion survey, landscape architects Hough, Stansbury and Associates were engaged to develop a phased

plan for improving the plant perimeter. The plans were required to dovetail with objectives of the local ratepayer's group, the municipality and the refinery.

The final plan as developed by the landscape architects, following several meetings with community representatives, called for a tree-planted berm as high as 18 feet along the north perimeter for the purpose of rendering the white storage tanks less visible. This work is well advanced, with planting being completed this spring. Subsequent phases will include a more varied treatment along the east fence-line laced with bicycle paths, a natural wild life sanctuary within the refinery property, increased access to the lake front plus an improved setting for an early pioneer home.

Figure 1 shows the general outline of the refinery and the location of the changes to which the refinery has committed itself. The cost is estimated at over $1 million assuming that the necessary fill can be obtained from refinery lands with the balance coming from future developments in the city.

The landscaping project was begun in 1976 and will be phased over several years.

Improved Control Over Noise

In recent years noise was recognized as an environmental problem and more than $500,000 was spent on numerous noise-reduction items. As each noise source was eliminated, lesser sources became apparent.

Over the preceding five year period, hundreds of spot-check measurements had been made daily along the sensitive east fence-line. These readings were supplemented by surveys conducted by Gulf's Research and Development Department and a private consultant. Source studies identified vents, flares, furnaces, large horse-power rotating equipment which were abated as far as practicable. By the end of 1976 this work was largely completed. But in spite of the abatement program, noise complaints continued at about the same level.

One of the significant facts which came to light was the large variation in noise levels recorded at the same location under identical plant operating conditions. Variations of 12-15 dBA were found to be commonplace. The reason for this extreme variability can be attributed to variable atmospheric conditions reinforced occasionally by sound coming from the nearby Lake Ontario shoreline.

The main question facing the project team was - could the lubricating oil modernization project be accomplished without a corresponding increase in community noise levels? The firm of Bolt, Beranek and Newman were engaged to answer this question. The consultant's report concluded that the main objection of the community was transient noise generated by plant upsets combined with unfavourable atmospheric conditions. They also concluded that steady state noise levels would have to be reduced.

Their computer models showed that shutdown of the existing lubricating oil facilities which are located closer to the

community than the new facilities, combined with further abatement of existing sources, would more than compensate for noise emissions from the new plant. The new facilities, of course, will be built to strict noise control standards.

Meetings With the Community

Separate meetings were held in October 1975 with members of the community to the north from which complaints are seldom received and those to the east from which we receive the bulk of complaints. These meetings were held in a local church hall and kept as informal but informative as possible. The main objective was to give each person a chance to ask questions and have them answered.

Several of the consultants who had been engaged explained the results of their studies using coloured charts and diagrams as much as possible. Questions were fielded directly from the audience by these consultants. Following the meetings, the attendees could visit the various displays set up around the hall and ask questions from various company experts. We found that many people are reluctant to ask questions in public so this approach filled a real need. Refreshments were served afterwards. In many ways the approach resembled the old town hall meetings which have unfortunately all but disappeared.

Maximum use was made of a small illustrated brochure which nicely summarized the environmental assessment document in lay language. This "mini assessment" tried to answer the commonly

asked questions with the main thrust aimed at the beautification program. This approach was well received by the local residents as it helped them to understand a rather complex situation.

Some of the Lessons Learned

In the course of this exercise several valuable lessons were learned. Some of these are worth comment.

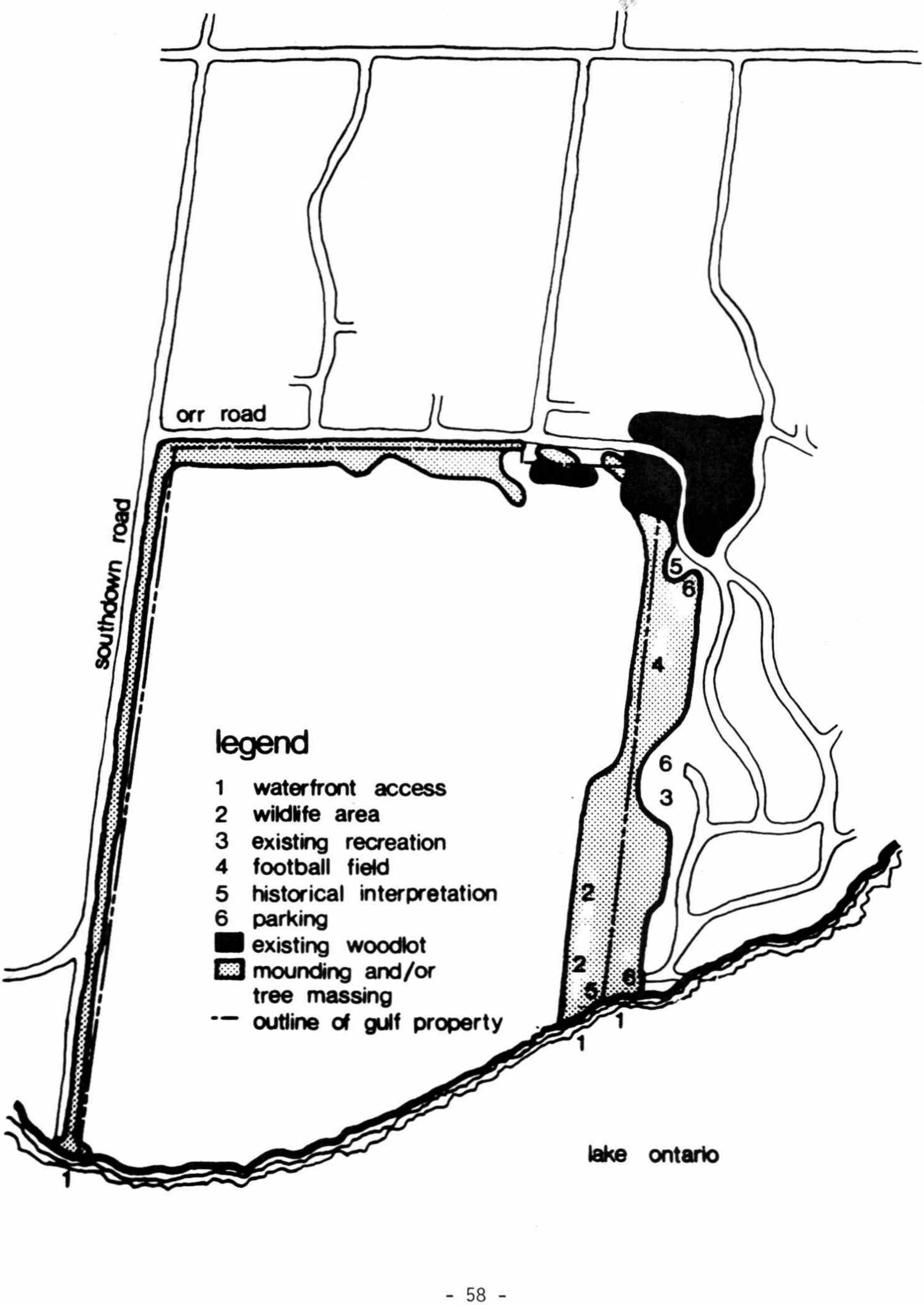
1. Supporting studies must be started as soon as their need can be identified. The assessment document depends upon these studies for authoritative information.
2. The electical power supply and flare system revamp proved to be difficult items which might have been finalized with less effort if greater in-depth investigation had gone into the assessment document.
3. An in-house environmental project team or steering group is essential, even though the bulk of the work may be done by outside consultants. This group can (a) steer the various studies; (b) provide co-ordination between the various departments internally, and (c) provide a balanced opinion on problems bound to arise in a large project.
4. Discuss your project with the Ministry of the Environment at the earliest possible stage. They have a much wider view point and can give valuable advice.

5. Co-ordinated communications inside and outside the company are essential. Employees, management, the press, ratepayer groups and various levels of government are all interested in a new project and sometimes they can provide valuable advice and assistance.
6. Commitments made by the proponent should be spelled out clearly and not couched in vague language.
7. In holding public meetings to explain a new project the format should be kept informal along the lines of the old town hall meetings. Nobody is on trial. Questions should be answered forth-rightly. Let the people who are most expert in their field answer the questions in their own way.
8. Preparation of a "mini assessment" summarizing the lengthier environmental assessment should be considered. Most people do not have time to read a thick volume.
9. An environmental assessment is not a highly technical document. The major decisions in fact may he highly subjective. It is assumed that regulatory requirements will be met.
10. Be prepared to alter your design so as to accommodate objections from the community.

Conclusions

This paper has attempted to highlight a few of the salient aspects of an Environmental Assessment in which the author was deeply involved. Some of this experience may help others in

the private sector as they move into a new era in which greater use of an impact assessment as a planning tool is envisaged although methods of preparing such documents are still fluid.


orr road
southdown road
legend
1 waterfront access
2 wildlife area
3 existing recreation
4 football field
5 historical interpretation
6 parking
existing woodlot
mounding and/or tree massing
outline of gulf property
lake ontario

SESSION II

Session Chairman
Dr. T. H. Tomlinson II
Vice President, Research and
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Montreal, Quebec

Recovered Sulphur — A Disposal Problem?
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University of Calgary, Calgary, Alberta

Control of Asbestos Emissions in an Urban Environment at Abex Industries
P. C. Milner
Plant Manager
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Odour Abatement Through Commitment and Participation
J. A. May
Safety Director
Rohm and Haas Canada Limited,
West Hill, Ontario

Criteria for Selecting and Evaluating Electrostatic Precipitators
Y. Goland
Chief Technology Engineer
Joy Manufacturing Company,
Los Angeles, California

RECOVERED SULPHUR - A DISPOSAL PROBLEM?

J.B. Hyne

Introduction

For almost a hundred years until the middle of the twentieth century sulphur and its oxidation product sulphur acid were universally regarded as a cornerstone commodity in the industrialised world. While it may not have lost that central importance, sulphur has acquired a number of new labels in the last 25 years. Among these new descriptions are involuntary co-product, environmental pollutant, glut on the market and even waste product. Why this relatively sudden change in sulphur's status?

By far the most important single factor must be the dramatic increase in the recovery of sulphur values from process streams whose principal raison d'etre has nothing to do with sulphur production per se. In the early 1950's the growing demand for natural gas as a clean and convenient fuel was already encouraging the production of hydrogen sulphide containing methane from sour natural gas deposits in both France and Canada. By the early sixties both of these regions were already delivering substantial quantities of very pure elemental sulphur to world markets. The day of dominance of the world sulphur trade by Frasch mined elemental sulphur was passing and the involuntary co-product of the energy industry was on the scene.

This "recovered" sulphur, however, was soon to be joined by a second kind of recovered sulphur - that removed from industrial and combustion effluents for reasons of environmental impact. The anti pollution era had arrived. Slowly but surely the biosphere's ability to absorb and disperse ever increasing quantities of sulphur dioxide was being overtaxed - at least in specific highly industrialised and populated areas. But for the energy crisis of the early seventies and the regulatory variances that were allowed to permit use of higher sulphur fuels the growth of recovered sulphur would have been even more dramatic. Sulphur thus acquired the pollutant label and inevitably the waste product one as well.

Despite these dramatic reversals in sulphur's image - although it has in fact never been seen as a very heavenly commodity - it still remains an essential item of world commerce. Over 50 million tons a year are consumed in various forms throughout the world and North America remains a major producer and consumer with over 20 million tons in all forms in 1976.

Have the developments of the last quarter century really introduced serious disposal problems as far as sulphur is concerned? Is it now or will it become a nuisance waste product? Will the problem, if it is a real one, get better or worse as demand for better control of effluents and the need to utilize alternate energy sources increase? Examination of the factors which determine the answers to these and other questions about sulphur is the basis of this paper.

The Nature of the Product

Sulphur exists in nature in a variety of oxidation states. Much of the sulphur in the earths crust is in the fully oxidised sulphate form, is environmentally stable and is of little concern in this study. Considerable quantities of sulphur, however, are in the free elemental zero oxidation state form, such as Frasch mined sulphur or in the reduced form as in metal sulphides, hydrogen sulphide or organosulphur compounds of petroleum, bitumens and coals. It is the oxidation state of this sulphur once it has been recovered and processed that determines the nature of the product and how it can be disposed of or used.

Fig. 1 illustrates the reduction - oxidation or REDOX scale of sulphur. From an industrial standpoint sulphur normally enters the system in the -2 oxidation state. This includes the H_2S of sour natural gas and petroleum processing, the metal sulphides of the non-ferrous metal industry and the organosulphur compounds of the fossil fuels. Without exception the sulphur exits the system in a higher oxidation state.

In the recovery of sulphur from H_2S the oxidation is strictly controlled so that the product is solid elemental sulphur in the zero oxidation state. This is achieved by the controlled oxidation Claus Process

$$2\,H_2S + 3\,O_2 \longrightarrow 2\,H_2O + 2\,SO_2$$

$$4\,H_2S + 2\,SO_2 \longrightarrow 4\,H_2O + 6\,S$$

The important points to note about this form of the sulphur product are that it is solid, relatively inert to containment vessels, relatively non-hazardous and still capable of being oxidised up the Redox scale with release of energy - in short it is a fuel!

In combustion or roasting processes, however, the oxidation of the sulphur values is not so restricted. The product that exits the system is sulphur in its +4 oxidation form, i.e. sulphur dioxide. This is gaseous, relatively corrosive, toxic and capable of either reduction or oxidation. It is seldom if ever stored or transported in this form. When effluent gas stream desulphurisation processes are considered they usually represent either reduction of SO_2 to elemental sulphur or the oxidation of SO_2 to the +6 oxidation state - sulphate. By far the bulk of the SO_2 produced by sulphide ore roasting is converted to the +6 oxidation state in the form of sulphuric acid. This is generally economically attractive because of the richer nature of these SO_2 streams, usually in excess of 10%,

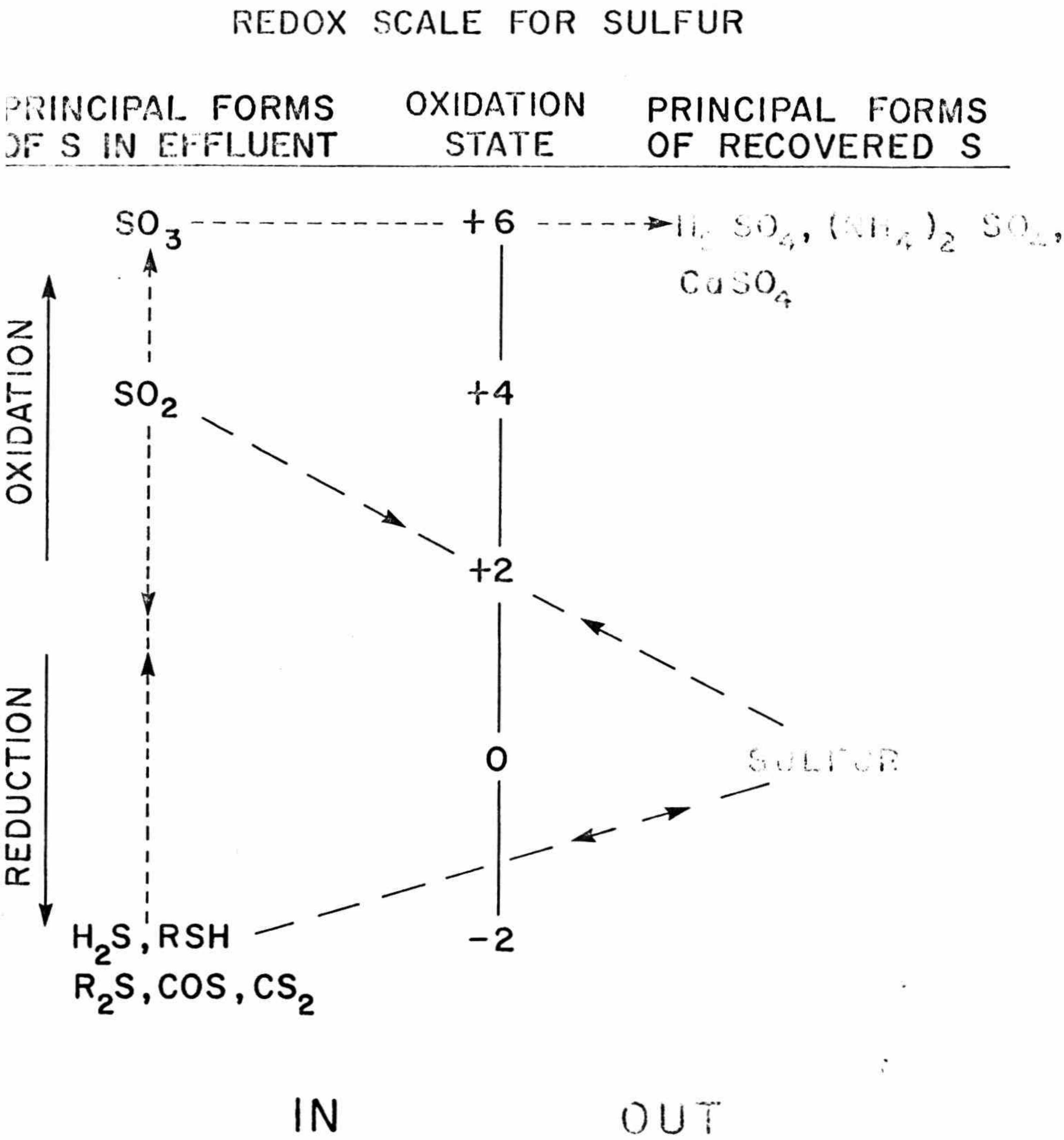
$$\underset{\text{air}}{2\,SO_2 + O_2} \longrightarrow 2\,SO_3 \xrightarrow{2H_2O} \underset{\text{liquid acid}}{2\,H_2SO_4}$$

The SO_2 content of fossil fuel combustion effluents, however, is normally much less and unless methods for concentrating the SO_2 are employed it is usually scrubbed out and simultaneously oxidised to a solid inorganic sulphate e.g.

$$SO_2 + \underset{\text{limestone}}{CaCO_3} \longrightarrow CaSO_3 + CO_2$$

$$CaSO_3 \xrightarrow[\text{air}]{O_2} \underset{\text{solid gypsum}}{CaSO_4}$$

FIGURE 1


REDOX SCALE FOR SULFUR
PRINCIPAL FORMS OF S IN EFFLUENT
OXIDATION STATE
PRINCIPAL FORMS OF RECOVERED S
SO_3
+6
H_2SO_4, $(NH_4)_2SO_4$, $CaSO_4$
OXIDATION
SO_2
+4
+2
REDUCTION
0
SULFUR
H_2S, RSH
R_2S, COS, CS_2
-2
IN
OUT

Many proprietry methods for achieving these oxidations are available to industry.

The SO_2, however, can also be reduced back to elemental sulphur. This is usually a more costly process in terms of energy consumption but is frequently dictated by factors such as concentration of SO_2 in the effluent and desire for a solid end product with some value. Reduction of SO_2 to elemental sulphur is commonly employed in treating coke oven gases.

Three types of end product can therefore be identified for "recovered sulphur". Two contain sulphur in the +6 oxidation state. One of these, sulphuric acid, is a considerable source of chemical energy and has a well known industrial value. The other, the solid inorganic sulphate (e.g. gypsum) has a very limited potential agricultural use as a soil sulphur source but is normally produced in such quantities as to represent a bulk disposal problem. Fortunately it is essentially inert and apart from dangers of upsetting biological ion balances can be disposed of in carefully selected dump areas as land fill or the like.

The third end product, elemental sulphur is in the zero oxidation state and like sulphuric acid has considerable commercial value. Indeed its energy potential is even higher than the product acid as will be discussed shortly.

Much of the sulphur values that will be recovered to minimise environmental impact will undoubtedly end up in the inorganic sulphate form and be disposed of as land fill or in ocean sinks. A very significant portion, especially that from richer sulphur containing effluents will either be recovered as elemental sulphur or converted to sulphuric acid. Where a choice is available as in the case of rich SO_2 effluents the direction to be taken on the sulphur redox scale will depend on a number of factors. Among them will be the cost of process energy, transportation and the market place for the product. We turn next to a consideration of the market place.

The Market Place for Recovered Sulphur

By any yardstick Canada is a major world sulphur producer. Of the better than 50 million tons of sulphur in all forms produced in 1975 - 1976 Canadian production was second only to the USA (see Fig. 2). Canadian production of elemental sulphur as opposed to total sulphur values represents an even larger proportion of world production.

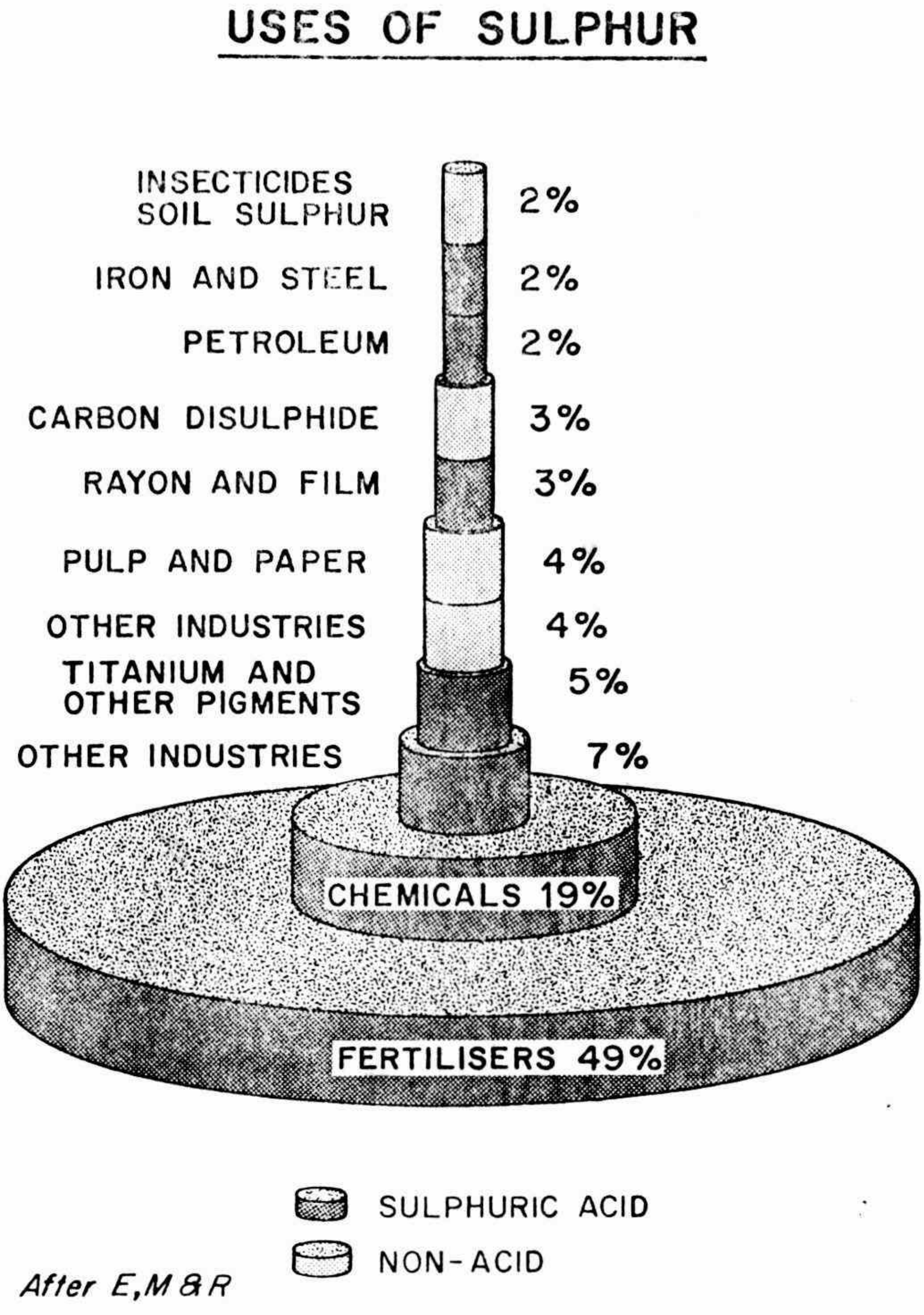
Although much is now being done to develop new uses for sulphur, as will be discussed later, the traditional uses still dominate the international sulphur market. As is seen in Fig. 3 by far the largest use is in fertiliser production. Industrial chemicals consume a sizeable 19% but most other segments of industrial community account for little more than a few percent. It has been estimated that the growth rate of traditional uses of sulphur on a world wide basis over the balance of the century will be between 3.5 and 4.3% depending upon economic growth rates in the industrialised countries and the rate of development in the third world. Of particular importance in the developing countries will be the degree to which agricultural sophistication can be introduced. Modern farming techniques would bring with them an increased demand for

FIGURE 2

MAJOR WORLD SULPHUR PRODUCTION

	All Forms	Elemental
	%	%
U.S.A.	29	37
Canada	20	28
USSR	19	9
Poland	9	13
Japan	7	2
France	5	7
Spain	3	--
Mexico	3	3
Italy	2.5	0.5
West Germany	2.5	0.5
	100%	100%

FIGURE 3


USES OF SULPHUR
INSECTICIDES SOIL SULPHUR 2%
IRON AND STEEL 2%
PETROLEUM 2%
CARBON DISULPHIDE 3%
RAYON AND FILM 3%
PULP AND PAPER 4%
OTHER INDUSTRIES 4%
TITANIUM AND OTHER PIGMENTS 5%
OTHER INDUSTRIES 7%
CHEMICALS 19%
FERTILISERS 49%
SULPHURIC ACID
NON-ACID
After E,M & R

fertiliser, a major sulphur consumer.

Generally speaking North America will continue to provide an annual excess of production over consumption. Western Europe should continue to be in a deficient position and be a major importer of North American production. A less clear picture emerges as far as other world areas are concerned. The Pacific Rim has in the past been a good export market for Canadian elemental sulphur but increasing recovery of sulphur values from industrial effluents and the introduction of middle east recovered sulphur may be threatening this market. The recent developments in Iraq and Saudi Arabia suggest that these two producers could, within the next decade move the Middle East and proximate areas into an essentially oversupply position with possible spill over into the attractive European market. Latin America is considered to be an area where supply and demand will remain in balance for some time although agricultural development in the Amazon basin could markedly effect the situation.

In short the major source of production for world markets will continue to be North America and the principal consumer will be Western Europe.

What of the scene closer at home? Fig. 4 gives an estimate of over production or short fall by region in the USA and Canada by 1985 (Manderson Associates Inc). The oversupply of some 5 million tons for Canada is considered by SUDIC (Sulphur Development Institute of Canada) to be conservative. Acid production figures from the Department of Industry, Trade and Commerce plus further deep sour gas production in the Alberta foothills formations could well add further production.

The 1976 Canadian elemental sulphur production was already at 7 million tons with 45% going to export markets, 45% being stockpiled and 10% consumed domestically. Of this 7 million tons less than 200,000 was from sources other than H_2S from sour natural gas. A further 600,000 to 700,000 tons of sulphur values was produced in the form of sulphuric acid principally from smelter gases.

The potential for disposal of Canadian recovered sulphur for the foreseeable future is therefore likely to be largely dependent on the export market. Local conditions, however, may well provide certain advantages to particular suppliers depending on such factors as energy balances and transportation costs.

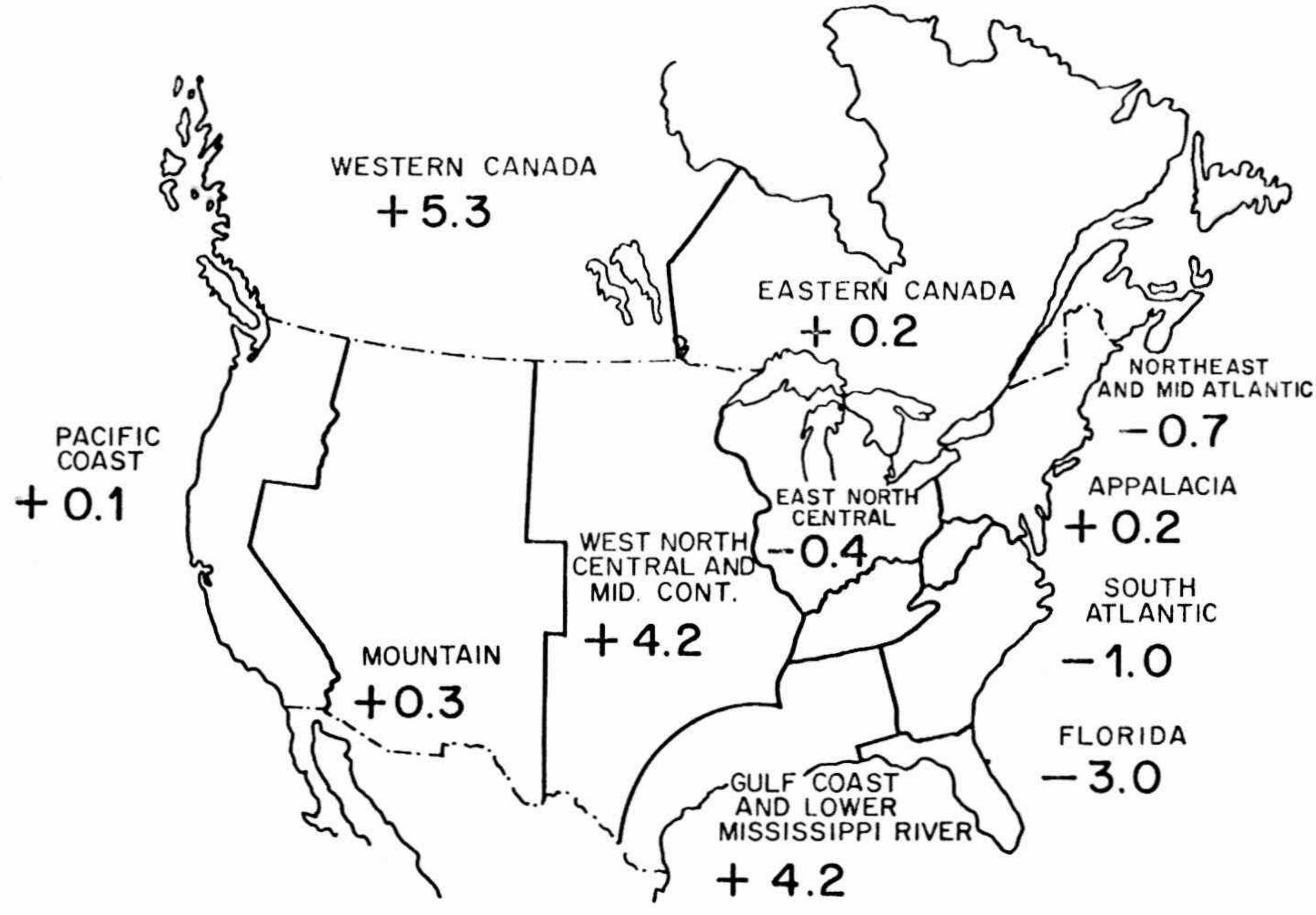
Marketing Factors

As has been noted elemental sulphur and sulphuric acid are the two principal forms in which recovered sulphur values are marketed. Although by far the major portion of the elemental sulphur is eventually also converted to sulphuric acid there are some important energy balance differences for the industrial consumer depending on which form is purchased. The oxidation reactions of elemental sulphur are exothermic, i.e. they produce heat

$$S + O_2 \longrightarrow SO_2 + \text{heat}$$

FIGURE 4

NORTH AMERICAN SULPHUR BALANCE BY REGION 1985



(Manderson Associates Inc, 1975)

$$2\,SO_2 + O_2 + 2\,H_2O \longrightarrow 2\,H_2SO_4 + \text{heat}$$

If the consumer receives sulphur values in the form of sulphuric acid rather than elemental sulphur the fuel value of the elemental sulphur during its oxidation to the acid is lost. In an energy integrated industrial chemical operation this energy must be made up by consuming ever higher cost fuel. With elemental sulphur at a relatively low price level its fuel value can therefore be a significant factor in the consumers decision as to whether to buy required sulphur values in the acid form or to make acid from elemental sulphur.

There is some evidence, however, that the increasing production of sulphuric acid from sulphide ore smelter gas SO_2 values has displaced Western Canadian elemental sulphur in Eastern and U.S. mid-west markets. Here the energy values lost are at least compensated in part by the savings in transportation costs. The balance, however, is clearly sensitive to changes in the price of sulphur, fuel and transportation all of which have, over recent years, not been noted for their stability.

Since by far the largest consumer of either elemental sulphur or product sulphuric acid is the fertiliser industry a major challenge to the use of sulphur in that field would have a dramatic effect on sulphur markets. Such a challenge did in fact occur in the 1960's when direct electric ore reduction of phosphate to elemental phosphorus threatened to displace the wet sulphuric acid method of extracting the phosphorus values from the phosphate ores. The rise in electric power generation costs however, and the drop in sulphur prices combined to maintain wet acid extraction as the economically preferred process. The illustration, however, does serve to emphasise yet again that sulphur marketability at both the domestic and international levels can be markedly effected by factors that on the surface may appear to be quite unrelated.

The increasing world wide use of higher phosphorus and nitrogen analysis fertilisers such as triple super phosphate and liquid ammonia rather than the higher sulphate containing materials has begun to show up in sulphur deficiencies in certain soils. While nitrogen and phosphorus are the principal growth nutrients required for high crop yields sulphur values are also essential although at a lower level. It has even been argued that as environmental protection measures continue to reduce the tonnage of SO_2 vented to atmosphere each year (estimated 100 million tons world wide - 1975) it will be necessary to compensate for some of this soil sulphur supply by increasing the sulphur content of applied fertilisers. The need for acid producing sulphur values in many basic soils in Canada is clearly established and in this use elemental sulphur is more easily and safely applied than sulphuric acid.

Perhaps one of the most active areas of research and development at this time as far as marketing sulphur is concerned is in the search for new and improved types of formed solid elemental sulphur. Until the late 1960's solid sulphur was normally transported in bulk form; that is simply dug from the solid storage block and shipped as a mixture of lump, powder and dust. Environmental and handling considerations resulted in the

introduction of slated sulphur and virtually all Western Canadian gas sulphur has been moving in this form since 1970. Although slate did represent an improvement over bulk its friability was found to increase with age and the search continued for an even better form.

At this time some twelve to fifteen new types of formed sulphur have been proposed or developed. Most represent some improvement over slate as far as friability is concerned but the degree of improvement is very variable. Water content and retention, which can be a problem for acid makers where foaming during the melting process can occur, is also an important factor for consideration. The list of "possibles" has now been reduced to some half dozen forms virtually all of which are generally spherical in shape. The forming methods can be classed as either wet or dry processes depending upon whether water or air are used as the heat sink during the conversion of the liquid sulphur feed to the solid form. Wet formed types include Sulpel (Monmax, Humphries and Glasgow) Capsul (Cambrian Engineering Group), Hydroprills (Commonwealth Oil Refining) and Chemsource (Foster Wheeler) while the air formed entries are Perlomatics (PEC Engineering) GX Granules (Procor Ltd.) and the Polish air prilled sulphur form.

What significance do these developments have for the "disposal" of recovered sulphur. There would seem little doubt that by the early 1980's a new type or types of generally spherically shaped solid sulphur form will be in the market place. While the bulk of domestic and continental sulphur shipments now move by liquid tank car, corrosion problems with liquid sulphur inventory tankage are beginning to suggest at least some replacement by new solid forms. All off-shore sales are of solid sulphur. If consumer acceptance of the new solid sulphur forms is as positive as early indications would suggest there could well be a significant swing to this mode of transportation and storage. A non-friable pelletised prilled or granule form of sulphur could lead to considerable revisions of handling systems including airvaying or other pneumatic transfer devices. The possibility of direct combustion of the sulphur pellet feed to produce SO_2 for acid manufacture without the added step of remelting with costly fuel consumption is also an attraction.

If such new types of formed sulphur are to be the preferred commodity form of the future it is important from an economic standpoint to consider carefully the point in the sulphur recovery process at which the forming is to be carried out. In the majority of currently available sulphur recovery processes, where elemental sulphur is the recovered form of the sulphur values, it is produced in liquid form. If allowed to solidify and subsequently be reformed an additional melting step is involved. Present high efficiency sulphur melters operate at close to $2 per ton remelt cost and this price is highly sensitive to fuel costs. While incremental cost estimates for the various forming processes are not yet all available it is unlikely that a figure of less than $2 per ton will be possible. This means that if the sulphur is not formed as it is produced in liquid form and requires remelting the cost per ton formed could double.

Future Canadian Sources

The likelihood of sulphur being produced in Canada for its own sake within the foreseeable future is remote. Recent exploration in the Sverdrup Basin of the Arctic Islands has indicated the existence of a possible large Frasch mineable deposit of elemental sulphur. Although relatively cheap energy sources may be available nearby the transportation costs from such a remote location would require sulphur prices many times their present level for economic viability.

Canada's present "oversupply" is almost entirely sour gas sulphur generated. Despite the projected peaking of western gas production late in this decade better than 150 million tons of elemental sulphur have yet to be produced from proven sour gas reserves. The recent increases in natural gas prices, however, have stimulated a return to deep drilling in the Alberta foothills. This is prime country for high H_2S containing hydrocarbon deposits and could result in a relatively more rapid increase in sulphur reserves than gas. Wells in the high foothills have shown H_2S levels as high as 90% - more a sulphur well than a hydrocarbon source!

Without venturing too far into the question of alternate energy sources for the future it is necessary that coal be examined briefly as a source of sulphur. Energy forecasters predict increased coal use both for direct combustion to raise steam and power and for gasification in situ or at surface to produce low BTU gases or SNG's. Coal combustion throughout the world is now the largest single source of anthropogenic SO_2 in the atmosphere with some estimates reaching 100,000,000 tons/annum. Recovery of even a part of the 50 million tons of sulphur content of this effluent could have an enormous effect on world sulphur markets. As indicated earlier, however, the sulphur values in such combustion effluents are usually too dilute to permit economic recovery as either SO_2 or elemental sulphur. The recovered sulphur values from such sources are more likely to end up as solid inorganic sulphates (e.g. $CaSO_4$) and be disposed of as land fill and the like.

As far as Canada is concerned only Eastern coals would provide a significant source of recoverable sulphur in gasification processes. These coals contain similar levels of sulphur to Middle East and Venezuela crudes i.e. about 3% sulphur. Western coals are relatively sulphur free containing less than 0.5% sulphur.

Recovered sulphur values from sulphide ore smelting are projected to increase substantially during the period to the end of the century. Energy, Mines and Resources estimated that metallurgical contained sulphur, which would likely be recovered as sulphuric acid, could grow from the 600,000 ton level of the middle seventies to close to 3 million tons by the year 2,000. This figure will, of course, depend heavily on growth in the non-ferrous metals industry and whether lower grade higher sulphur containing ores are processed. It is unlikely, however, that anything less than a doubling or tripling of sulphur recovery will be experienced.

Much has been said about the Alberta Oil Sands as the key to

future long term self sufficiency for Canada as far as fluid hydrocarbon fuel is concerned. Relatively little, however, has been reported about the concomittant sulphur production of this huge hydrocarbon resource is even partially developed. The bitumen of the oil sands contains between 4.5 and 5% sulphur. If the 300 billion barrels of potentially recoverable hydrocarbon were ever processed the sulphur recovered would range from 750 million to 2 billion tons depending on the process used!

There seems little doubt that the oil sands will continue to be developed. The principal unknown is at what rate. Sulphur from the oil sands is, like sulphur from sour gas, an involuntary product and its production rate will depend on the hydrocarbon production. Roughly speaking each million barrels per day of production will yield 5,000 tons/d of sulphur, something less than a quarter of current Alberta production from sour gas. The present and committed production facilities in the oil sands (GCOS and Syncrude) will produce something less than 200,000 bbls/d or approximately 1,000 tons/d of sulphur. There are presently 5 gas plants in Alberta that produce more than 1,000 tons/d of sulphur each. In short it will be some time before the sulphur from the oil sands even approaches present sour gas sulphur production.

Estimates developed by SUDIC, EMR and IT & C all suggest that without further significant deep sour gas finds in the foothills formations present sour gas sulphur production will probably decrease before oil sands recovered sulphur productions grows sufficiently to counterbalance the reduction. Even with the balance point coming as late as the early 1990's however, it is unlikely that Western Canadian sulphur production will drop much under 5 million tons per annum to the end of the century. Coupled with a present inventory of better than 20 million tons Canada will undoubtedly be continuing to look for export markets and new uses for her sulphur production.

The Search for New Uses

The search for new uses for elemental sulphur is not a new activity. It may have received recent impetus from the involuntary production of recovered sulphur in excess of world demand but Frasch producers were exploring new sulphur composites with waste materials in the 1930's and a stabiliser for polymeric sulphur has long been sought.

Canadian interest in new uses grew with the development of the western sulphur industry. Alberta Sulphur Research Ltd. (ASR) was founded in 1964 with one of its aims being the exploration of the new use field. In the early seventies following a National Research Council study of the Sulphur Development Institute of Canada (SUDIC) was formed with support from the Federal and Alberta governments and the sulphur producing industry. UNISUL, the University of Calgary Interdisciplinary Sulphur Research Group was established in 1974 with support from the National Research Council. Both SUDIC and UNISUL have major programs in the new use area with SUDIC funding development work principally at the commercial level and UNISUL concentrating on laboratory studies. Work at McGill University in the early seventies was also directed

toward new sulphur composites for use in construction. It is clearly appropriate that the world's second largest sulphur producer have an active research and development program in new sulphur uses.

It is important to recognise at the outset that the attitude of "getting rid of the stuff" is not and never has been an element in the work of serious sulphur new use researchers. Despite the fact that recovered sulphur values are sometimes classified as waste products the serious search for new uses has always been based on finding products or processes that represent an improvement over existing materials or technologies. While any new use filling these pre-requisites would be a valuable development it was clear from the outset that large tonnage new uses would be needed to have a significant market effect. Such considerations immediately pointed to the fields of construction, road building, insulation, coatings and similar areas where commodities are traditionally consumed in volume.

Sulphur Foams

One of the main disadvantages suffered in using solid elemental sulphur as a construction material is its tendency to crystallise on solidification from the melt. This results in an open internal crystalline matrix which gives the material undesirable physical properties. Sulphur, however, can be readily foamed yielding a light weight strong material with excellent thermal insulation characteristics. Recent development work on sulphur foams has been led by Chevron Chemicals in collaboration with SUDIC. The product is essentially elemental sulphur containing a chemical which will release carbon dioxide when a further blowing agent is added to the melt. The final foam which can be formed in place contains 85% sulphur and a one inch thickness has the equivalent insulating capability of one foot of gravel. Prospects are good for northern use to insulate permafrost from pipelines, industrial installations and other heat sources. The material has also been tested as an insulating sub-base in road construction at sites in Calgary and on the Dempster Highway near Arctic Red River in the McKenzie Valley. Reduction in gravel requirements and load on the subsoil are further advantages. The good insulating properties and high compressive strength suggest that use as a subsurface in Canadian road construction might minimise frost heaving. A fully instrumented test section has already shown much reduced frost penetration below the foamed sulphur compared with with a traditional road section. A complete line of new application equipment has been developed and sucessful trials are still being conducted. Of the several new uses currently under development, however, foamed sulphur is one of the products nearest full commercial development.

Sulphur Asphalts

The increasing demand for maximum utilisation of hydrocarbons as fuel sources has both reduced the availability of asphalt and increased its cost. The possibility of replacing some of the asphaltic bitumen in road paving materials with elemental sulphur has attracted the attention

of a number of companies.

SUDIC has been supporting a development program for a Thermal Asphalt containing asphalt, sulphur and low density aggregate. When employed as a full depth paving it provides protection against frost penetration and minimises winter frost heaving. Although costs are somewhat higher than regular asphalt no special equipment or road bed preparation are required making this product most attractive in areas where frost heaving is a problem. UNISUL engineers are also active in the sulphur/asphalt paving work.

Shell Canada has been developing and testing their Thermopave product for a number of years. The principal advantage of this material is that by adding 13% sulphur to the mix the normal aggregate requirement can be replaced by sand. This is particularly attractive in areas where quality aggregate is in short supply. While only minor modifications of the paving plant system appear to be required more extensive changes in the paver and paving techniques are involved. Thermopave has been extensively tested throughout the North American continent. Recent test programs sponsored by the Texas Transportation Institute, the Sulphur Institute and the U.S. Bureau of Mines (Bumines) suggest possible extensive applications in the U.S.A. where many areas exist with little aggregate availability but abundant sand.

Bumines has most recently tested sulphur/asphalt/sand mixtures as patching material for airport runways. Previous patching tests had been successfully conducted on roadways. Mixtures containing 13 - 15% sulphur, 6 - 8% AR2000 asphalt and 75 - 80% sand proved successful in patching runway cracks as wide as 3" and as deep as 17". The material was trowelled into the cracks at 130°C (± 10°C) and aircraft were using the runway one hour after application. The quick setting feature of the material is clearly an advantage in heavy traffic areas.

Of even greater importance in the attempts to reduce asphalt consumption in road construction are the developments in the use of sulphur asphalt emulsions. Society National Elf-Aquitaine (SNEA) in France, Gulf in Canada and RM Hardy in collaboration with SUDIC (The Pronk Process) have all developed emulsion type processes. The key to each of the processes is the method of dispersing the sulphur in the asphalt and stabilising the resulting sulphur in asphalt emulsion. SNEA has been conducting a major paving program in France using up to 30% sulphur in the asphaltic binder. The binder has a lower viscosity than straight asphalt, making mixing and application easier. The sulphur/asphalt/aggregate mix could be transported in open trucks up to 50 Km. Long term performance tests now underway are reported to be yielding excellent results.

The Gulf product incorporates up to 50% sulphur in the sulphur asphalt binder representing a very significant asphalt saving. High shear rate mixing is employed to form the emulsion. Tests have been conducted in Alberta and Ontario using normal paving procedures. Results so far indicate good performance under normal traffic use conditions. The Pronk Process is similar to the Gulf process using

40% sulphur but is reported to involve a simpler binder emulsion preparation which could result in more attractive economics of operation.

Sulphur Concretes

Sulphur concrete is in essence a traditional concrete in which the Portland Cement binding agent for the aggregate has been replaced with elemental sulphur. Much of the recent work on this promising construction material has been carried out in Canada. The UNISUL group at the University of Calgary has an ongoing program of research, development and testing which is directed at the design of an optimum mix and the simplification of formulation and application procedures. Sulphur Innovations Ltd. of Calgary, a company established by Dr. Alan Vroom after his study of the Canadian sulphur scene in the early 1970's for the NRC is now producing a variety of Sulphurcrete products. These include pipeline swamp weights for the oil industry, parking lot bumpers, highway median barriers and sidewalk slabs. Work at McGill University on sulphur concrete building blocks was begun in the early 1970's by Ortega and Rybczynski and developed to the point where an actual house was constructed from precast interlocking sulphur concrete blocks. SUDIC has also maintained an active interest in the development of sulphur concrete.

A typical sulphur concrete might contain 45% coarse aggregate, 25% sand, 28% sulphur and 1 - 2% air. This is essentially similar to Portland Cement Concrete except that sulphur replaces the cementitous material (normally cement and water) and the porosity or air content is somewhat lower in the sulphur concrete. Both of these differences, however, can be important. Construction with traditional concrete under Canadian winter conditions is both costly and difficult because of the freezing of the water component. The absence of water in sulphur concrete removes this problem but, in addition sulphur concrete cures or matures much more rapidly than portland cement concrete. Sulphur concrete has attained better than 90% of its final fully matured strength after 48 hours while a similar strength in conventional concrete requires nearly 3 weeks. This, coupled with a reduced need for heating to prevent freezing could obviously result in considerable savings through use of sulphur concretes for poured in place applications under northern or winter conditions.

Despite the attractiveness of sulphur concrete in low temperature environments it was earlier noted that simple sulphur concrete compositions suffered from freeze-thaw cycling fatigue. Loss of dynamic modulus of elasticity after some 20 temperature cycles typical of Canadian winter conditions was dramatic. Addition of iron sulphides, however, was found to modify this effect equally dramatically and compositions of sand sulphur and pyrite could be prepared that showed little loss of modulus after as many as 250 cycles.

UNISUL work has demonstrated the marked effect that even trace amounts of hydrogen sulphide can have on the compressive strength of sulphur concretes. This is particularly important considering that the source of much of Canada's sulphur is H_2S and ppm level H_2S residues in the sulphur are inevitable. The effect is most dramatic in the case

of sulphur itself but even in composites some residual weakening effect is noted. However, use of pyrrhotite, a less sulphur rich iron sulphide than pyrite, virtually removed any H_2S effect on the sulphur concrete compressive strength. It is now generally believed that the effects of both H_2S and the iron sulphides are connected with their ability to interact chemically with the sulphur and effect the stability of the long chain polymeric form.

The importance of porosity in the manufacture of sulphur concretes was noted earlier. This is primarily related to the ease of penetration of water into the sulphur concrete. The freeze-thaw action of included water will obviously result in severe internal stresses but additional water penetration permits the invasion of soil bacteria into the sulphur concrete. Work is still continuing on the stability of sulphur concrete in contact with soil containing thiobacilli which are known to consume sulphur with the production of acid.

Other materials have been tested as additives to sulphur concretes particularly to improve tensile as opposed to compressive strength. Chopped glass fibres at levels of 1% have a noticeable effect on impact resistance and the use of a very fine aggregate can render the sulphur concrete mixture pumpable for spray applications such as soil stabilisation. The Japanese have patented a formulation which includes 3% of the ethylene-vinyl acetate copolymer and the Bumines have used dipentene and dicyclopentadiene additives both of which are capable of interacting with and stabilising the polymeric sulphur content of the sulphur concrete.

Some work has been done on pre-fabricated and reinforced materials particularly from the standpoint of corrosion of the steel reinforcing. Sulphur and steel are compatible materials in the absence of water but corrosion occurs rapidly if water is present at the interface between the two materials.

Sulphur concrete is an attractive new use material that could provide an additional market for large tonnages of sulphur. Its commercial development to date has not been as extensive as that of sulphur/asphalt but continuing effort promises to find the optimum design and application for the material.

Agricultural

Increased or new specialised uses for sulphur in agriculture are being actively explored. While sulphur deficient soil areas are still being identified and tested for crop response to sulphur application, work is continuing on improved methods of applying sulphur and better control over the rate of assimilation of the sulphur. Work on this aspect is currently being carried out by the UNISUL group at the University of Calgary.

Agri-Sul, a company now operating in Texas and Alberta has produced a readily biodegradable form of elemental sulphur containing

bentonite. This mineral expands on contact with water thus aiding in the breakdown of the solid sulphur and allowing easier bacterial invasion that is essential for soil assimilation.

The Australians through their Soils Division of CSIRO have introduced a new form of superphosphate fertiliser called Biosuper. This fertiliser by-passes the traditional sulphuric acid extraction of phosphate rock to yield phosphoric acid for subsequent conversion to superphosphates. The native rock phosphate is pelletised with 17% sulphur and innoculated with thiobacilli soil bacteria. These bacteria produce sulphuric acid from the sulphur "in situ" which releases soluble phosphate nutrient from the rock phosphate at the plant root site. While costs have been reduced more work is necessary to achieve the second goal which was to attain better control over the rate of release of the phosphate. Much of the applied phosphate fertilisers, especially in high rain fall areas are lost in run-off.

An even more exciting and potentially very valuable development in the agricultural field has been the sulphur coating of water soluble fertilisers. Imperial Chemical Industries (ICI) and the Tennessee Valley Authority (TVA) have both been active in the development of sulphur coated urea (SCU). ICI's product has been marketed under the trade name Gold-N. The primary aim of SCU is to control the rate at which the water soluble nitrogen nutrient (urea) is released into the soil and to reduce losses through run-off. Coating the urea with a suitable mixture of sulphur and a wax sealant still leaves pinholes in the sulphur coating through which the water soluble fertiliser can be leached. Soil bacterial attack on the sulphur coating will also eventually break down the outer shell and the sulphur will be incorporated into the soil as a nutrient also.

Some work has been done on varying thickness and structure of the coating in an attempt to obtain better control of release rates. If the mechanism of coating degradation can be fully controlled the possibility exists of formulating a fertiliser with various proportions of pellets designed to release the inner soil nutrient at times varying from a few weeks to as long as a year or more - a sort of agricultural Contact C! The effect such a development could have on the fertiliser transportation and application industry would be enormous spreading as it would the load of work over a much longer time period than the present annual Spring application.

Coatings

As indicated previously the biggest endeavour in the recent efforts to find new uses for sulphur has been in the major tonnage areas of construction, paving and agriculture. Nonetheless there have also been interesting developments in smaller but important new use areas.

Among these particular mention should be made of sulphur coatings. Bumines has been active in the spray application of a sulphur coating to the external surfaces of concrete blocks as the

only binder for the blocks. No mortar or other binder is used between the courses yet a strong wall structure can be developed.

Dale of the South West Research Institute (SWRI) in San Antonio, Texas has patented a sprayable composition for coating and stabilising mine walls. The material contains 87% sulphur, 8.7% talc, 2.6% fibre glass and 1.7% dicyclopentadiene (DCPD). Unsaturated hydrocarbons as DCPD are common additives for sulphur composites since they tend to stabilise the long chain polymeric form of elemental sulphur thus giving the material additional elasticity.

Flammability is a common concern in any structural application of sulphur. While the element does not burn readily it does oxidise under combustion conditions to yield sulphur dioxide which is unacceptable except in very low concentrations. A number of combustion inhibitors are available, however, which can be added to sulphur composites in sensitive applications. As an illustration Idemitsu Kosan Co. of Japan has a non-flammable sulphur coating containing approximately 95% sulphur, 2.5% styrene (the polymer stabiliser) and 2.5% triphenylphosphite as a flame retardant. Lower concentrations of the phosphite ester are partially effective but complete inhibition requires the higher level. Cost factors are obviously important in determining whether these relatively expensive additives can be employed.

An extension of the sulphur coating concept is also being examined in the use of these composites for various soil sealing and stabilisation applications. Leakage of environmentally unacceptable contaminants for process tailing or settling ponds requires effective sealing of the retaining soil structures. Similar sealing is important in irrigation systems to minimise water loss from the conducting ditches and catchment basins. Work to date by such organisations as Bumines and SUDIC has demonstrated some success but questions still remain unanswered regarding soil microbial attack on the sulphur based sealants.

Sulphur Impregnation

Sulphur impregnated, infiltrated or indurated concretes and ceramics have attracted world wide research and development attention. Danish, French, Italian and Spanish work has highlighted European endeavour while Bumines and Malhotra at CANMET in Canada are among those active on the North American scene. Impregnation of concretes with other materials has the primary effect of raising compressive strengths. Ordinary high quality concretes have compressive strengths of the order of 5,000 psi while polymer impregnated concretes (PIC) can have values as high as 20,000 psi. Use of sulphur as the impregnating agent for concrete (SIC) avoids the high cost of the organic polymer and yet yields SIC materials with compressive strengths of 10,000 to 15,000 psi depending on the method of impregnation. Sulphur content of 10 - 12% can be obtained.

Like the sulphur based coatings, SIC materials are highly resistant to attack by acids and salt solutions making them particularly

attractive for marine structure applications and heavy chemical industries. Sulphur impregnated concrete pipe has shown considerably improved resistance to attack in such applications as sewage collection and treatment.

Sulphur impregnation of ceramic tiles has been shown to improve ageing due to reduced porosity and to enhance resistance to frost breakage probably for similar reasons. Increases in flexure strength of impregnated tiles have been noted up to 100%.

Interface Binders

Wood laminates have also been developed using a sulphur based binder. Ethyl Corporation has patented a 75% sulphur, 25% plasticiser composition for bonding wood or hide together in laminates. Since the material being laminated is no less flammable than the sulphur based binder no retardant is included in the formulation. However, in the event of fire the sulphur binder would produce the more toxic SO_2 compared with primarily CO_2 from fuel combustion of wood. The plasticiser is again chosen from a group of chemicals capable of reacting with the long polymer sulphur chains and stabilising them. Organic polysulphides, unsaturated organic compounds as used in the Japanese and SWRI coatings mentioned above and dimercaptans are among the additives employed.

A number of concrete manufacturers have been interested in sulphur based mortars for specialty applications. Melt-and-pour mixtures of sulphur with inert fillers such as silicates and carbon black have long been known with much of the early work being conducted by Druecker and associates from Texas Gulf Sulphur in the 1930's. Ageing of the mortars due to loss of sulphur plasticity and the formation of crystalline material has long been a problem. As in the cases described above use of additives capable of reacting with the polymeric sulphur and inserting into the long chain of sulphur atoms has improved mortar properties. Thiokol in amounts from 0.5% to 2.0% has been successfully employed. The main advantage of such sulphur based mortars is enhanced resistance to acid attack which is often a problem in industrial chemical storage and processing situations.

Other Developments

Among the many other new uses for sulphur and sulphur compounds that are currently under development mention should be made of one or two of the more unusual kind. Considerable work has been done over the last decade by British investigators on the development of the sodium-sulphur battery. The Ford Motor Company has also been active in this field. Considerably high energy densities can be obtained with this battery compared with lead/acid and similar storage devices but the need for operation at elevated temperatures makes it more suitable for continuous operation applications rather than stop/start usage. British interest has been focussed on use in electric powered rail locomotives.

The emergence of chemical lasers as a practical device also suggests the possibility of a carbon disulphide laser. CS_2 lases when burnt with oxygen in the appropriate configuration. While this would be an interesting new use for a sulphur compound it would not represent an end use since the product of the CS_2 combustion is SO_2, the increased recovery of which has stimulated the search for new uses.

Finally sulphur dioxide itself has been put to new use in leaching phosphate rock for fertiliser production in a process devised by TVA. SO_2 has also been used in the treatment of silage to give higher food values in the cattle feed after preservation.

Conclusions

There is little doubt that for some time to come Canada will be producing or recovering a great deal more sulphur than is consumed domestically. Traditional export markets for the element will vary with world economic strength but increasing efforts on the part of other countries to recover effluent sulphur values will tend to reduce reliance on foreign sources. It is appropriate that Canada should be in the forefront of research and development in the search for new and improved uses for sulphur not only to establish new markets but also to enable this valuable resource to be upgraded in Canada before sale abroad.

ODOUR ABATEMENT

THROUGH

COMMITMENT AND PARTICIPATION

By: J.A. May

Listening to the chairman introduce me reminds me of the chairman who had to introduce a substitute speaker. In the introduction, he wanted to emphasize that this was no ordinary substitute. THIS WAS SOMEBODY GOOD.

He likened this to when a pane of glass breaks in a window. He pointed out - one can use a rag to plug the hole ...... or

one can use a pane of glass.

Well, he went on, I can tell you our speaker this evening is no rag, but is a real . . . . pane.

A common concept heard today is that the Philosophy of Industry has changed. Today Corporations have become aware of their social responsibilities.

BALONEY!!

Business today is no different. The objective is - and always will be - maximize profits. This is as it should be.

The difference today is that a great number of better executives recognize that if their social responsibilities are not met today in such areas as: Pollution Control, Safety, Health Protection and Energy Conservation, Profts will be down tomorrow.

These executives realize that lack of action by the Corporations in social areas will precipitate more government intervention, and, therefore, inhibit the management of their business.

Our Vice President of Manufacturing objected to the inclusion of Safety and Employee Health Protection within the context of Profit Motivation, within this paper, with justification.

Undoubtedly there is justification for objection by many industries.

This is not intended as a Black and White condemnation of all industry.

I WOULD SUGGEST IF THE SHOE FITS

WEAR IT

Because of lack of responsibility by some businesses in the U.S.A., the O.S.H.A. act came into being. Currently in Ontario a new omnibus bill is being prepared by the Ministry of Labour which, like the U.S. O.S.H.A. act will, undoubtedly restrict management flexibility. The new Ontario omnibus bill will be forced upon all industry in Ontario because of the lack of response to employees genuine needs by some employers.

Industry must respond to the need for protection of the environment, or face the consequences. Industry must recognize that the general public of today is better educated and informed than their predecessors. The public realizes that they can collectively exert tremendous political pressure to achieve their goals, and no longer is the giant corporation beyond this sphere of influence.

Mutual mistrust is prevalent between the media and industry. This is most unfortunate, however, is understandable. Media coverage is always of the negative aspects of pollution abatement by industry, with little recognition for conscientious effort.

Responsible media coverage of environment topics have also gone a long way in helping the general public obtain actions against those industries which take the stand that they will do nothing about pollution abatement until forced into it.

Media Bias Must be Understood and Accepted

This reminds me of the story of the man who took his son to the zoo in London, England.

> When the child was at the gorillas' cage, he soon became attracted with the gorilla and kept getting closer and closer to the cage until the gorilla reached out and grabbed him. An Irishman in the crowd immediately jumped into the cage, clubbed the gorilla over the head and rescued the child.
>
> A media representative standing by said outloud ...."AH!!! A brave Englishman rescues child from vicious gorilla".
>
> The Irishman, on hearing this, pointed out that he wasn't English, and that only an Irishman would do such a brave thing. The media reported the next day:
>
>> "Mad Irishman breaks into private compound and clubs child's pet to death".

An Editorial in the March issue of Modern Power and Engineering explains where we are at present.

> The crackdown is coming - and it's being hastened by a handful of companies that have taken the position "We're not going to do anything to clean up pollution until we are forced to do it".
>
> As the Ontario report says "In the present economic and legal context, companies have a powerful financial incentive to continue polluting the air and water". With fines of up to $10,000 per day possible under the Ontario acts, successful prosecutions could rapidly remove this financial incentive. That's why the report concludes that "an increase in prosecutions is the most promising way of reducing the pollution caused by the pulp and paper industry".
>
> The same principle applies to other industries. Most firms have made great strides in bringing their pollution control operations up to acceptable levels. If the handful of laggards need prosecution and stiff fines to get them to follow suit, they've only got themselves to blame if that's exactly what they get.
>
> There's a limit to the amount of patience environment officials should be expected to have. The general public has certainly long since lost patience with the foot-draggers.

Based on what we have learned from this editorial and others like it, it is essential that those industries which have not yet realized their responsibilities, do so before it is too late.

All industry, <u>no doubt</u>, could bear the consequences for the lack of action of only a few.

Rohm and Haas recognized back in the late 60's its' "SOCIAL RESPONSIBILITY" or consequences for lack of responsibility, however, the "HOW" to achieve the environment objective of reducing odour releases from our West Hill plant was not easy to find.

It was by constant visits from the Ministry of Environment, who we all think have little to do but interfere with legitimate business, that the solution began to appear. Through meetings held with representatives of the Ministry, it was decided that a definite program was needed in order to reduce the number of odour emissions from our West Hill plant.

It was also mutually agreed at that time that we would not take the formal "Program Approval" route but would instead achieve our goal through mutual cooperation with the Ministry.

From this point onward, Rohm and Haas was no longer just involved in an odour abatement program, but was committed to it's success.

Like Delsey, there is a definite difference between just being INVOLVED or being COMMITTED.

There is a parable that defines this difference:

> One day there was a chicken and a pig walking down a dusty, dirty road when they came upon some "filthy

dirty, hungry" children who were "crying" and had no place to sleep. The pig and chicken felt very sorry for the children and the pig suggested they do something for them.

With this the chicken said:

"I know what we can do, lets feed them.

<u>LET'S GIVE THEM BACON AND EGGS!!!"</u>

As you can see - The chicken was <u>involved</u>

The pig was <u>committed</u>.

<u>THE MORAL BEING:</u>

(If you're going to be committed to environment control, you have to put your butt on the line!).

In all seriousness, a special thanks goes to members of the Ministry who worked with us during the period when we were establishing our abatement program. While they were working with us on our program, they were also under political pressure from residents around our plant. Not once did they detour from the concept that abatement could be achieved through cooperation.

The problem at the West Hill plant, probably not unique, was that one of the main chemicals handled at the plant, although not a particular health hazard, did have a very low odour threshhold. The odour threshhold for E.A. (Ethyl Acrylate) is less than half a part per billion. This means that only ounces, spilled during unloading of a jumbo tank car, can result in complaints from local residents.

Constant or large persistant E.A. odour emissions were and could be virtually

eliminated through technological means, however, spurious discharge through operator error could not. Therefore, employee participation was an essential part of our overall program.

From this point on in the presentation, slides were used to illustrate various steps taken in our abatement program. The comments associated with some of these slides follow:

SLIDE #2 The Rohm and Haas plant was built in West Hill in 1953, 54 when the area was virtually in the country, however, over the years this has become a residential area and homes are just about to the plant fence line.

To take the attitude that we were here first, therefore, will do nothing about pollution, is an unacceptable approach.

SLIDE #5 Because of our success with our safety programs at our plant (ONE LOST TIME INJURY IN 7 YEARS), it was decided that we should follow the same format on odour abatement - <u>Enlist the Participation of all our employees</u>. It is my firm belief that employees:

Want	To do a good job
Like	To know how they are doing
Seek	Recognition for good work
Need	To know weaker points
Can	Improve performance

Management, however, must demonstrate to the employees that pollution abatement was important - as important as production, profit and safety, and that we firmly believed that our neighbours had a right to live free of plant odours.

SLIDE #7 A form was prepared for recording odours for either the Ministry. Local Residents or our own employees. In particular, we asked our employees to report to supervisors any time they detected odour. This could be while working or when coming to or leaving the plant.

It was through these reports that we were able to track down our main problem areas.

SLIDE #8 From these reports, we were able to establish priorities for our abatement program.

A priority was established from a combination of Severity and Frequency. For example, a not so severe odour release which occured infrequently would have relatively low priority in our abatement program. One which occured frequently with high to medium severity would have a High Priority in our program. Cost factors were not considered at this stage.

SLIDE #9 Once we had established priorities, we then prepared the program schedule which now included cost factors for review with the Ministry. The timing limitations within the schedule were those mostly imposed by equipment suppliers rather than a reluctance to move on our part. Status reviews were also held with the Ministry periodically.

SLIDE #10 Reports from our employees indicated that bottom unloading of jumbo rail cars was one of our major problems and correction of this should be placed high on the priority list. They pointed

out that it was almost impossible to disconnect unloading hoses without spillage.

SLIDE #11 Top unloading using dry break connectors was introduced to eliminate this particular problem.
Other problems associated with rail cars were not under our direct control.

SLIDE #12 However, using the tank car defect report, our employees were able to point out specific defects found.

SLIDE #13 The form, along with a sketch, was then sent to our supplier for corrective action.

SLIDE #14 This initiated many modifications to the rail cars, such as removing the bottom valve and blanking off the outlet.

SLIDE #15 During unloading, the vapour displaced from the storage tank by the contents of either rail car or tank truck was directed back to the carrier. Carriers arrived full of liquid and left full of vapour.

SLIDE #16 Can pumps or pumps with mechanical seals were installed at the unloading stations to eliminate the possibility of leakage from the pump packing glands.

SLIDE #17 The reports indicated that one of the main problems inside the plant was leakage from the monomer meter actuator valve packing

gland and also drainage of the meters when maintenance was required (which was often).

THE ANSWER TO THIS WAS

SLIDE #18 To change the monomer meters to turbine type. The turbine type meter has no direct contact with the liquid but instead is activated by an electronic signal.

SLIDE #21 Our first vapour scrubber which scrubbed the monomer vapours from our original small emulsion reactor system, is basically a caustic tank with caustic solution being pumped from the bottom of the tank through a venturi nozzle while drawing vapours from the reaction units.

THIS HAD LIMITED CAPACITY

SLIDE #22 When we expanded our emulsion facilities, we then installed our first scrub tower. This is a 40 ft. tower packed with Tellerette packing. Caustic solution is pumped from our original scrubber tank to the top of tower and free falls through the Tellerettes discharging back to the tank. Vapours are drawn from the processing units through the tower in the opposite direction to the caustic flow, thereby effectively removing the vapours.

SLIDE #23 The scrubbed air is then discharged from the top of the stack at the 125 ft. level. This system is 98% effective.

SLIDE #24 Another problem inside the plant was the odour release into the plant while dropping some batches to the blend tanks. The released odour would eventually find its way out through windows and doors to our local residents. To overcome this problem, we sealed the blend tanks and directed the vapour to our scrub tower. We were not using the scrub tower when the batch was dropping and had adequate capacity.

SLIDE #26 Scrub system efficiency is monitored periodically by our chemist using Gas Chromatography. We have found the scrub tower efficiency to be extremely stable providing the caustic solution strength is maintained.

SLIDE #27 We also encountered odour emission from our laboratory which was detected by our employee reporting system. Installation of a 90 lb. carbon filter on the laboratory vent discharge appears to have corrected this.

SLIDE #28 At the suggestion of the Ministry, we installed a wind direction monitor on top of one of our buildings, tied into a recorder in the foremans' office.

SLIDE #29 These records were most helpful in determining if a complaint had indeed been caused by Rohm and Haas or if it originated from some other source (which was sometimes the case). These records were also made available to the Ministry who were able to determine the predominant wind direction in the West Hill

area. I believe this was used in the Johns Mansville asbestos investigation.

SLIDE #30 The E.A. storage tanks are equipped with conservation vents. Under normal operating conditions, no vapours are released to the atmosphere. The maximum pressure generated by solar heat is 1/2 lb. and we have pressure relief valves set at 3 lbs. The system is pressure tested on a monthly basis during an unloading operation.

SLIDE #31 A Ful-Flo filter pot is installed on the E.A. transfer line inside the building. Periodically the filters require changing by maintenance personnel, however, before this can be accomplished the pot must be drained of E.A.
We have not yet solved this problem, however, because this is a low frequency operation, we rely on favourable wind direction and local exhaust ventilation to achieve this.

SLIDE #34 We have tried to incorporate all the best features in our recently completed emulsion expansion and have hopefully done so.

SLIDE #35 For instance - No longer do we have to drain our filters into an open pail when changing filters, we have installed a permanent drain line on the bottom of the filter which allows us to drain the contents of the filter pot directly back to the storage tanks.

SLIDE #36 We have also exclusively used turbine meters in this latest expansion.

SLIDE #38 The new emulsion tank, like the other, is tied into the new scrub tower system.

SLIDE #39 One of the added features on the new reactor is a normally open air operated valve on the vapour extraction line to the scrubber. In the event of a foam-up or pressure build up in the reactor, the valve is automatically closed by sensors in the reactor, thus preventing plugging of the tower by a foam-out.

SLIDE #40 Each of the lines from each processing unit have been provided with valves for flow adjustment and connections to extract samples. These features like many of the others were incorporated at the planning stage rather than being afterthoughts.

SLIDE #41 The vapour scrubber for this emulsion unit is a two tower system operating in series. 80% of vapours from process are scrubbed in the 1st packed tower and reservior and 80% of the remaining vapour is scrubbed in the 2nd tower and reservior. One of the advantages of the two tower system is that, should one tower become plugged, the other tower can then be operated independently.

SLIDE #42 Despite our efforts, we still received one "Violation Notice" in 1976.

THE NOTICE READS

Did Permit Discharge of a Contaminant
Into The Natural Environment That Did
Cause Material Discomfort.

It was my pleasure this afternoon making this presentation.

I hope I have not caused you too much Material Discomfort.

CONTROL OF ASBESTOS EMISSIONS IN AN URBAN ENVIRONMENT AT ABEX INDUSTRIES LTD. LINDSAY, ONTARIO

by

P. C. Milner

Introduction

As its title indicates, this paper is concerned with the control of emissions of a hazardous material in a specific location. During the course of the paper we hope to show how the existence of a problem was recognized in the past, how it was dealt with over a period of many years, and how recent developments in environmental concern and available technology have made possible both a more accurate assessment of the problem and what is hoped will be a permanent solution.

Before getting down to our specific plant situation, let us take a brief look at the hazardous material with which we are concerned.

Asbestos

This versatile material is actually a family of fibrous hydrated silicates. The three most important types are chrysotile (white) amosite (brown) and crocidolite (blue). 95% of the world's production is chrysotile, and the three leading producers are Canada, the Soviet Union and Southern Africa. What makes asbestos so unique is that its fibres, when combined with other materials, provide protection from fire, absorption of heat from friction, insulation from heat, cold and noise. It has high mechanical strength and

stability, is non-flammable, inert and very difficult to break down and destroy.

These qualities make it very useful in a wide variety of products such as roofing, piping, floor tiling, fire-resistant partitioning, protective clothing, brake linings, clutch facings, gaskets, filters and many more. Unfortunately there are health hazards associated with prolonged exposure to asbestos. Inhalation of substantial quantities of airborne asbestos dust over a period of several years can cause asbestosis, lung cancer, and in rare cases mesothelioma, which is a cancer of the lining of the chest cavity. Recent medical studies have also linked asbestos with cancer of the gastro-intestinal tract.

Considerable research has been done on asbestos-related diseases, but it is sufficient for our purpose to say that degree of exposure and period of exposure are critical points, and it is generally agreed that the periods of exposure considered to be hazardous are quite lengthy, extending over many years.

The hazard of asbestos in the workplace has long been recognized by manufacturers using this material, and preventive measures taken. These include individual exhaustion of machines, avoidance of spillage, wearing of respirators, etc. Standards have been established by the Ontario Ministry of Health and the prevailing legal limit of in-plant exposure is two fibres greater than 5 microns in length per cubic centimetre of air on an eight-hour time-weighted average basis.

This of course refers to the in-plant situation, but we are concerned in this paper with the protection of the environment outside the plant, where the general population is more or less permanently exposed to whatever is in the atmosphere.

The Ontario Ministry of the Environment has set a tentative ambient air criterion for asbestos of 0.04 fibres greater than 5 microns in length per cubic centimetre.

Plant Operation

The Lindsay plant of Abex Industries Ltd. has been in operation since 1947. It is situated on an 8 acre site in a mixed industrial and residential area. We are manufacturers of friction material, usually referred to as brake-lining, for use on passenger cars, trucks, trailers, buses, earth-moving machinery and railroad cars.

Asbestos comprises about 40% by weight of most of our formulas. It is used because of its ability to absorb heat produced by friction, and because, in combination with other materials, particularly phenolic resins, it can be molded into particular shapes, and cured, resulting in a material which can be cut, ground, drilled, and otherwise machined.

Some of the other raw materials used are solvents, graphite, carbon black, sulphur, lead powders, barytes and rubber.

A brief description of our production process is seen in Figure 1.

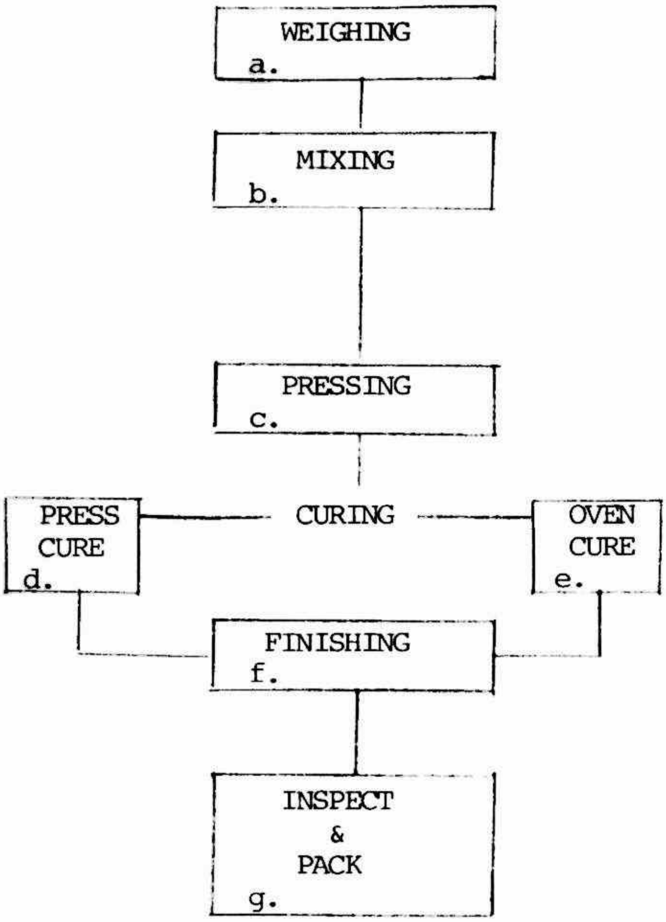
Dust Control Method Prior to 1976

Each dust-creating source, whether it be a weigh station, preform press, drill or grinder, is individually exhausted by a specially-designed hood connected by ducting to a dust collector.

This has been the case since the opening of the plant thirty years ago, but over the years many improvements have been made both in hooding and in the type of collector employed.

FIGURE NUMBER 1

PROCESS FLOW DIAGRAM



a. Weighing - raw materials are proportioned into containers or directly into blenders.

b. Mixing - rubber milling, horizontal and vertical mixing equipment are employed to blend the various raw materials. This procedure takes place in normal room temperature (20° C).

c. Pressing - Mixed compositions are formed or molded into rough size and shape.

d. CURING - formed shapes are oven
e. or press cured.

f. Finishing - cured shapes are machined to finished size by a series of cutting, grinding and drilling operations.

g. Inspect and Pack - Finished components are inspected, marked and packed.

The original collectors were of the Schneibel type, operating at a maximum of 10,150 c.f.m.

In 1963, the Schneibel collectors were replaced with Rotoclone type N wet scrubber collectors. The Rotoclone operated at 13,000 c.f.m. and was estimated to be 97% efficient in peak condition. These units were installed in the weighing and mixing area, press area and a third in the finishing area, to give a total capacity of 39,000 c.f.m.

The type N Rotoclone cleaned the air by the combined action of centrifugal force and a thorough inter-mixing of water and dust-laden air. The dust was separated from the water by means of a water curtain, created by the induced flow of air through a stationary impeller at a high velocity which caused the dust particles to cling to the water molecules. This process cleaned and cooled the air and discharged it outside the plant. The water was re-used continually and the dust waste collected in a sludge hopper and trucked to the town of Lindsay sanitary landfill site at the rate of 3000 gallons of sludge per day. The solid waste was separated from the water carrier in settling ponds, and the residue buried.

Eventually there was no space available for settling ponds, and the town was therefore unable to accept sludge for disposal, as it could not be buried in the thin slurry form.

As a result, we purchased a Barret 401-CL centrifuge to effect the removal of solids from the scrubber water in such a manner that they could be easily disposed of as solid waste. The cost of this equipment, installation and operation exceeded $17,000 and it was only partially successful.

Ministry of the Environment Survey & Recommendations

In the meantime, concern over asbestos emissions to atmosphere was increasing, and it was felt by certain authorities that wet scrubbers were allowing asbestos fibres to escape in inadmissible quantities.

In June 1975 an in-depth survey of the plant was carried out by the Peterborough District Office of the Ontario Ministry of the Environment.

During this survey we advised the Ministry which machines were serviced by each of our three collectors and we discussed the calculation of emissions to atmosphere.

The emissions from each collector were calculated having regard to:

(a) the handling points and machines serviced

(b) the total production by product line

(c) the percentage of asbestos in the formula for a given product line

(d) spillage and other wastage

(e) assumed efficiency of the scrubber

On the basis of total 1974 asbestos consumption we arrived at an estimated total emission rate of 0.2867 lbs. per hour.

Subsequent to the survey, the Ministry installed High-Volume Filters at various locations adjacent to the plant, for the purpose of collecting asbestos fibres from the ambient air.

At the end of August 1975, the Ministry completed their survey report, the findings of which were as follows:

1. On several instances prior to and following the survey, notably June 13, July 7, 14, 22 and August 11, visible emissions of 20% opacity and greater were observed from the finishing area Rotoclone.

2. Using asbestos emission rates developed by Abex, the total plant asbestos emission rate was found to be 0.2867 lbs/hr. or approximately 2 pounds per ton of asbestos processed.
3. When the emission rate from (2) above was used in the virtual source program, ground level concentrations at the south lot line and the residential area to the south of that line were found to be 8.6 and 8.3 ug/m^3 (micrograms per cubic metre) respectively. The proposed allowable concentration at the point of impingement is 5 micrograms per cubic metre of air.
4. If the asbestos emission rate developed by the United States Environmental Protection Agency, 6 pounds per ton of asbestos processed, were used, the concentration would be substantially higher than those quoted in (3) above.
5. Of the total emission rate of 0.2867 lbs/hr., 0.2416 lbs/hr. or approximately 85% emanates from the finishing area Rotoclone.

The Ministry of the Environment therefore recommended that we install a high efficiency dust collection system to replace the finishing area Rotoclone and complete such an installation by June 30, 1976 and also initiate engineering studies towards replacing the remaining Rotoclone dust collectors.

Dust Control Equipment Design and Procurement

The Company acted quickly to implement the Ministry's recommendations.
A survey was conducted to define our flow requirements in each area of the plant. The Finishing Area exhaust sytem in particular was subject to a very thorough examination as shown in Appendix 1. A total velocity of 14000 c.f.m. was recorded at the fan inlet, and from this data drawings and tentative specifications were prepared by our Facilities Engineering Department located in Mahwah, N.J.

Basically, our specification covered a dry bag type dust collector using a compressed air reverse pulse cleaning action and having an air-to-cloth ratio of approximately 8 to 1 and a volume of 20,000 c.f.m.

Tenders were called, and by December 1975 a decision had been made to award the contract to Wheelabrator Corporation of Canada, subject to approval by the Ministry, of the proposed collector.

At this time it was the Company's intention to install one bag-type collector to service the Finishing Department, and replace the remaining two Rotoclones over a period of two years.

However, during December 1975, results became available from the monitors which had been installed outside the plant, and these results indicated that the Ministry's tentative ambient air quality criteria for asbestos were not being met.

As a result, it was decided to speed up the conversion program, and to aim at having one baghouse in operation by the end of August 1976, and the remaining two by the end of that year.

After still further consideration it was finally decided that from the standpoint of convenience and cost it would be more practical to replace all three wet collectors at once by the simultaneous erection of three Wheelabrator "Ultra-Jet" High Energy Pulse Dust Collectors using a common stack.

Accordingly, a contract was awarded to Wheelabrator Corporation for the supply and erection of this equipment on a turnkey basis.

Our Company had previous experience with Wheelabrator when similar bag-type collectors were installed at our Winchester, Virginia Plant.

FIGURE NUMBER 2

EXPENDITURE

Description	Cost
Ultra-Jet continuous reverse air cleaning bag type dust collectors. 3 units complete with all structual steel, air compressor, air dryer, air blowers and motors, complete screw conveyor system, control system including starters and capacitors Turnkey project involving start-up totalling:-	\$230,000.00
Pelletizing system including control panel, screw feeder, drum, hopper, hopper level controls and miscellaneous motors, speed reducers and fabricated items:-	\$ 14,600.00
Electrical control wiring on dust collectors and pelletizing equipment:-	\$ 12,700.00
Continuous particulate monitor package:-	\$ 5,400.00
Construction of a 1500 KVA, 44,000 volt to 600 volt, substation, control wiring, switchgear, distribution transformers complete Turnkey project totalling:-	\$112,000.00
Pavement re-surfacing local to installation:-	\$ 5,800.00
Total:-	\$380,500.00

There was one additional problem.

The three dust collectors totalled 92.5 horsepower, requiring 100 KVA in addition to the 500 KVA being supplied by Lindsay Hydro. Since Lindsay Hydro were already at their maximum it was necesary to construct a 1500 KVA, 44,000 volt to 600 volt substation, complete with all wiring, switchgear and distribution transformers.

All erection and electrical work having been completed, the collectors were put into operation in mid-October, 1976.

Figure 2 shows final cost breakdown.

<u>The "Ultra-Jet" High Energy Pulse Dust Collector</u>

A dry bag type, with a compressed air reverse pulse cleaning action, No. 1512TA, Model 108, Modular Top Access Compartment, having an air to cloth ratio of 7.93 to 1 with a cloth area of 2520 square feet to filter 20,000 CFM of dust laden air. A Chicago Blower Centrifugal Fan #30, designed to handle 20,000 CFM at 14" static pressure at ambient temperature of $70^{o}F$. During normal operation, 4" to 6" pressure drop across filter bags is typical. In each bag house there are 180 (15 rows of 12) 16 oz. dacron filter bags, 6" diameter and 108" long. These modular units are mounted side by side on a free standing structure at the north side of our plant approximately 25 feet from the building, Figure #3 refers. From each dust collector, a 30" dia. duct runs over the roof to the area serviced, one duct to the weighing and mixing area, one to the pressing area and a third to the finishing area, Figure #4 refers. Within the plant, in each area, runs a network of overhead ducting adequately sized to suit each individual machine and material handling point.

FIGURE #3: ARRANGEMENT OF DUST COLLECTOR.

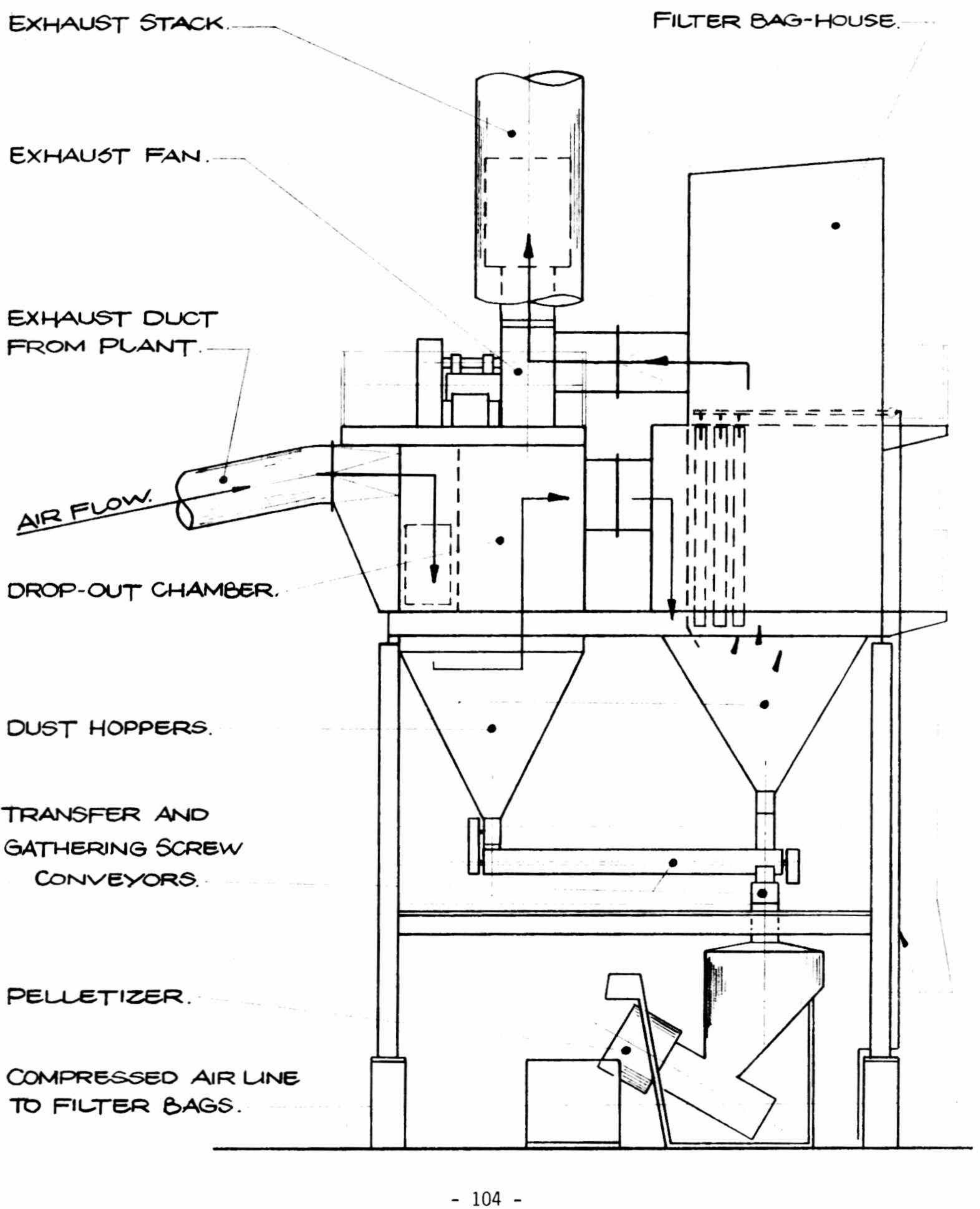
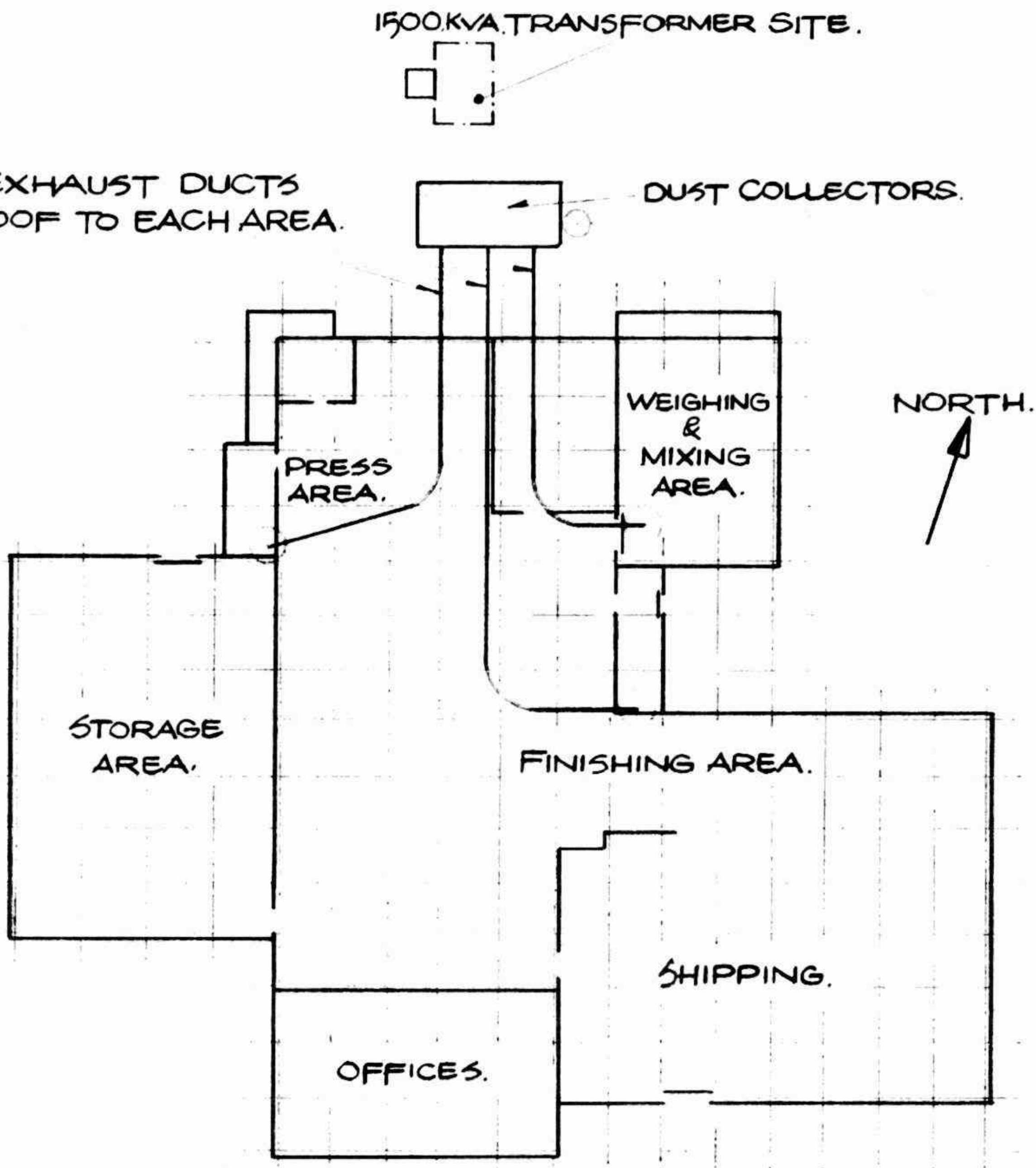


FIGURE #4: ROOF DUCT SCHEMATIC.



ABEX INDUSTRIES LTD., LINDSAY, ONT.
PLANT AREA = 76,000 SQ. FT

The dust laden air exhausted from the plant first enters a drop out chamber where the air flow is obstructed which causes the larger, heavier particles to fall into a hopper below. This is a safety measure that prevents any particles that may be extremely hot from damaging the dacron filter bags, thus reducing the risk of fire. The air stream then enters the filter baghouse through an inlet high in the housing. There a specially designed baffle plate deflects the dust-laden air around the surfaces of all the filter bags, reducing the velocity and creating a downward dust flow within the baghouse. This downward dust flow causes heavier particles to settle into the collecting hopper below. Lighter dust remaining airborne is uniformly deposited on the external surfaces of all the filter bags. This uniform distribution allows the ultra-jet filter system to use higher air-to-cloth ratios than would otherwise be possible.
The high air inlet location and baffle plate helps extend filter bag life by eliminating high upward dust velocities and reduces re-entrainment and lower end bag abrasion , common in hopper entry designs operating at comparable filter rates.
Once a uniform cake of dust has been formed on the filter bags, it is instantaneously removed by a sudden, precisely controlled blast of compressed air into the filter bag which causes the bag to expand instantly to its maximum diameter, throwing the dust from the outer surface. As the air blast dissipates, the bag returns to its normal filtering configuration. The dislodged dust falls into the collection hopper below. A sequential timer controls the pulsing of each row of bags, usually every 30 minutes. The cleaned air from each collector unit is exhausted through a common 4.5 foot diameter, 95 foot high stack.
During cleaning cycles, dust precipitation to the hopper is aided by the downward flow of incoming air. Once the dust is in the hopper, it is not subject to re-entrainment.

The dust collected in the hoppers is transported by a series of transfer and gathering screw conveyors feeding a storage hopper in the pelletizing room. Figure #3 refers.

The pelletizing system, or dust agglomerator, was designed by our divisional engineering staff, Winchester, Virginia and built in Lindsay. The dust is fed from the storage hopper by a screw feeder into a rotating drum, water is added at a controlled rate which results in the formation of solid moist pellets. These pellets self feed from the revolving drum into a hopper for eventual removal daily by a local disposal service to the town of Lindsay industrial waste disposal site where they are buried.

Dust Collector Maintenance

A continuing maintenance program has been introduced since start-up date to help ensure satisfactory uninterrupted operation. This program entails a daily check on instruments such as the baghouse manometer, fan motor ammeter and air pressure at compressor and air manifold located at the baghouse level. All instrument readings are recorded.

On a weekly basis, a complete mechanical inspection takes place. Screw conveyor drives, rotary valves, bearings, compressed air system, door seals and drive belts are included and any signs of wear, leakage or any other abnormality is recorded and reported immediately.

In accordance with a directive made by the Ministry of the Environment, a sub-contractor was hired to complete an in-depth inspection of our 3-180 bag

ultra-jet high pulse dust collectors every three months. An inspection report is then completed and a copy is forwarded to the Ministry of the Environment. A complete record of all activities relating to maintenance of our dust collection system is available to any visiting environment officer.

Monitoring of Dust Emissions

In order to monitor the exhaust stack on a continuous basis when any of the dust collectors are operating, an Ikor Model 2710 In-stack Continuous Particulate Sensing Monitor has been selected and purchased.

This Ikor Monitor utilizes the charge transfer process for continuous non-extractive particulate monitoring.

Dissimilar solid materials come into physical contact with an electrically isolated sensing probe in the flowing air outlet stream, a charge transfer results in the flow of an electric current, which is electronically processed into output voltage directly proportional to particulate mass concentrations.

Simplicity was the key word when the choice of a continuous in-stack monitor had to be made. The Ikor Model 2710 Non-extractive Particulate Sensing Monitor is relatively maintenance free and easily installed and operated with a strip chart recorder being built directly into the portable control unit.

To date, the required stack testing and sampling required for calibration of our monitoring device remains incomplete. Mid-June has tentatively been set by our Environmental Control Department, Chicago, and Facilities Engineering, Mahwah, N.J., for this activity.

It has been agreed Abex Industries Ltd., shall make a preliminary and three runs of stack sampling for particulates. The samples taken from one of the runs shall be made available to the Ministry of the Environment and the balance of the samples

analyzed by Abex. The sampling shall be in accordance with the Ontario "Source Testing Code - 1973".

In addition to forming part of the process of calibration of the monitor, this stack sampling will comply with one of the conditions laid down by the Ministry of the Environment when they approved our proposed installation. Their approval was subject to a satisfactory stack test.

High volume filters have been located outside the plant since the new collectors became operational last October. The Ministry advises us that samples have been submitted for evaluation, but at the time of preparation of this paper, results are unfortunately not available. We are confident that emissions will prove to be in compliance with current criteria.

Conclusion

We have experienced very few operational problems with this installation, and there has been no instance of process interruption.

The management of Abex Industries Ltd. and its U.S. parent company Abex Corporation, has always been conscious of the need to monitor and improve in-plant working conditions and to minimize interference with the outside environment.

For many years, our Industrial Hygiene Department in Chicago and our Facilities Engineering Department in Mahwah have assisted the manufacturing divisions in a continuous program of improvement in these areas.

Because of the wide diversification of our parent company, these specialist departments have considerable experience of a great variety of environmental control problems.

As a result, we in the Lindsay Plant were able to respond quickly and positively to the Ministry's recommendations.

Contacts between Company people and Ministry officials were frequent, cordial and co-operative. This undoubtedly assisted in the speedy completion of the project.

You will realize from this case history that improved environmental protection did not come cheaply. Compliance with the Ministry's recommendations involved us in capital expenditures to the extent of almost $400,000.

Nevertheless, we feel we have a dust control system of which we can be proud, and which stands as evidence of Abex's stated aim of being a good neighbour in the community.

APPENDIX 1

EXHAUST DUCT VELOCITY SURVEY

#1 ROTOCLONE-FINISHING DEPARTMENT

#1 ROTOCLONE ROOF STACK = 30 INCHES DIAMETER

VELOCITY READINGS (PITOT TUBE): -
1) 3000 FPM
2) 2500
3) 2900
4) 3000

AVERAGE VELOCITY = 2850 FEET PER MINUTE

VOLUME = 14,000 CUBIC FEET PER MINUTE

#1 ROTOCLONE FAN INLET = 30 INCHES DIAMETER

VELOCITY READINGS : -
1) 2600 FPM
2) 2500
3) 3000
4) 3200

AVERAGE VELOCITY = 2825 FEET PER MINUTE

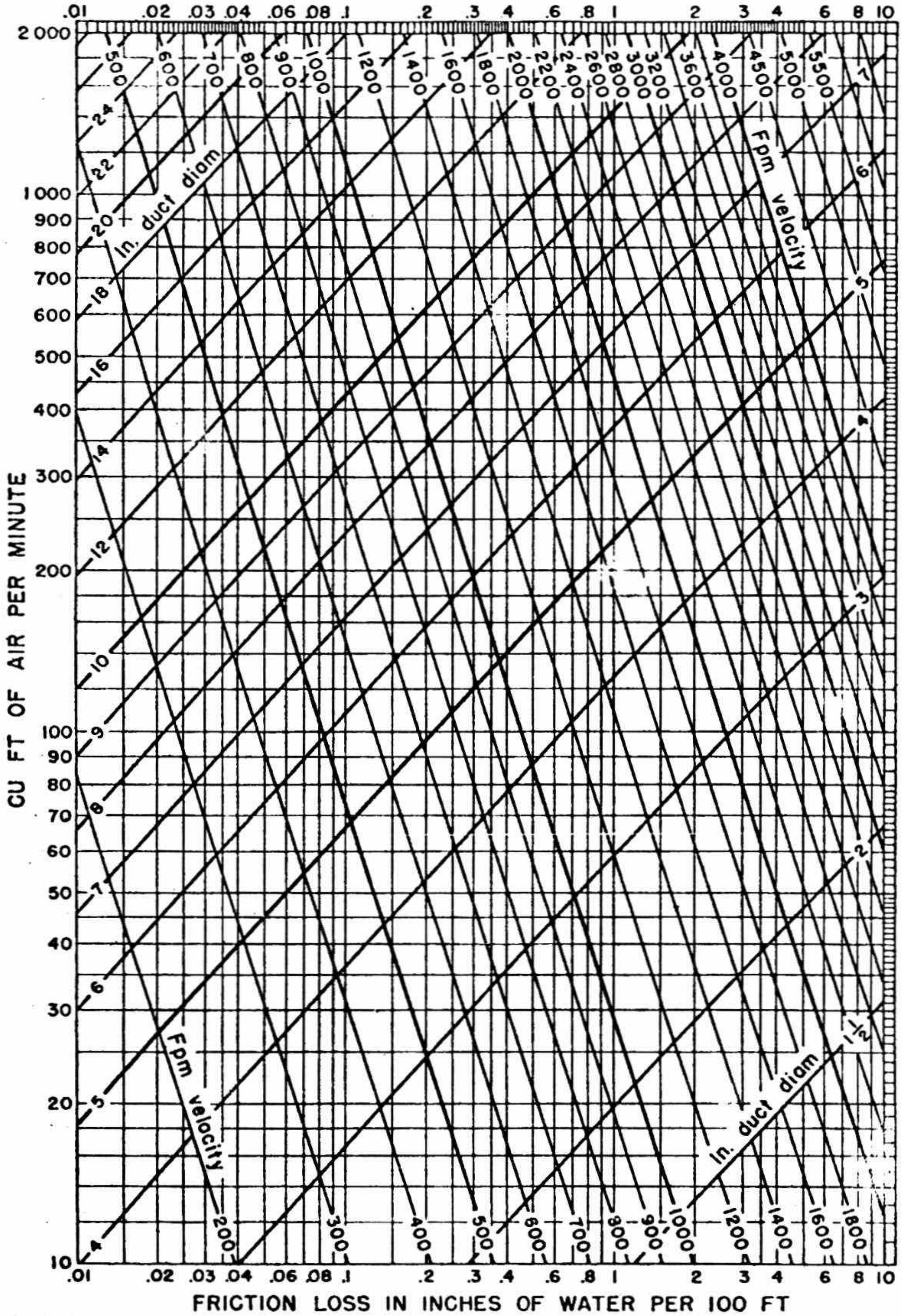
VOLUME = 14,000 CUBIC FEET PER MINUTE

No. of Br. or Main	Dia. of Pipe in.	Area of pipe sq. ft.	Air vol. CFM in branch	in main	VEL in FPM	Length of Pipe in Ft. St. runs	no. of elbows	equiv length	total length	RESISTANCE IN INCHES OF WATER GAUGE per 100'	of run	one VP	orifice loss VP	hood suct VP	hood suct.	total resis.	Gov SP.	Branch entry
AA	5	.1364		550	4030	23	1-90 1-20	5+1	29	4.7	1.36	1.01	0.6	1.6	1.62	2.98		--
AB1	5		550		4030													
AB	7	.2673		1100	4115	38	--	--	38	3.4	1.29					1.29		--
AC1	8	.3491	1500		4295													
AC	11	.6600		2600	3940	10	--	--	10	1.85	.185					.185		
AD1	4	.0873	350		4010													
AD	11			2950	4470	2	--	--	2	2.35	.047					.047		
AE1	9	.4418	1700		3850													
AE	14	1.069		4650	4350	6	1-90°	1.7	23	1.7	.391					.391		
AE1	6	.1904	800		4075													
AER	5		600		4400													
AE3	8		1400		4010													
AF	16	1.396		6050	4335	13½	--	--	14	1.4	.196					.196		
AG1	5		600		4400													
AG2	6		800		4075													
AG	8		1400		4010													
AH1	8		1400		4010													
AH2	11		2300		4240													
AH	20	2.182		8850	4055	2	--	--	2	.92	.018					.018		
AJ1	5		600		4400													
AJ2	6		800		4075													
AJ3	8		1400		4010													
AJ	21	2.405		10250	4860	6½	--	--	7	.96	.067					.067		
AK1	4		350		4010													

No. of Br. or Main	Dia. of Pipe in.	Area of pipe sq.ft.	Air vol CFM in branch	Air vol CFM in main	VEL in FPM	Length of Pipe in Ft. St. runs	no. of elbows	equiv length	total length	RESISTANCE IN INCHES OF WATER GAUGE per 100'	of run	one VP	orifice loss VP	hood suct VP	hood suct	total resis.	Gov SP.	Branch entry
AK	22	2.640		10600	4015	5½	1-70°	23	29	.81	.235					.235		
AL1	4		350		4010													
AL	22			10950	4150	1½	--	--	16	.85	.136					.136		14
AM1	5		550		4030													
AM2	6		800		4075													
AM	8			1350	3865													
AN1	6		800		4075													
AN	10	.5454		2150	3940													

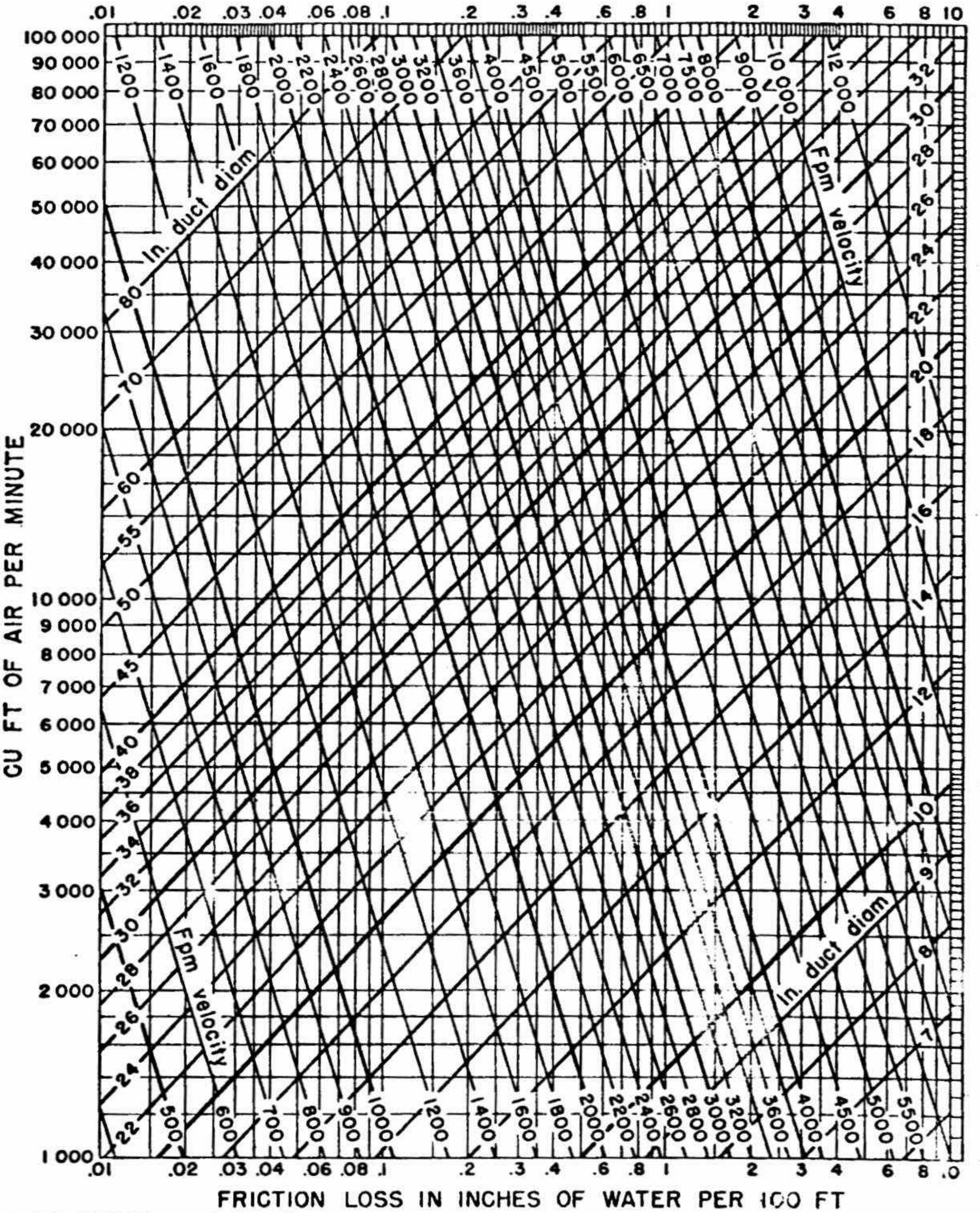
EXHAUST SYSTEM RESISTANCE CALCULATIONS
#1 ROTOCLONE-FINISHING DEPARTMENT NOV. 1975.

No. of Br. or Main	Dia. of Pipe in.	Area of Pipe sq.ft.	Air Vol. CFM in branch	Air Vol. CFM in main	Vel in FPT	Length of Pipe in feet: St. runs	no. of elbows	equiv. length	total length	Resistance in inches of Water Gauge: per 100'	of run	one VP	orifice lossVP	hood VP suct.	hood suct.	total resis.	Gov. SP.	Branch entry
AP1	7		1200		4490													
AP	12	.7854		3350	4265													
AQ1	7		1100		4115													
AQ	14			4450	4165													
AR	26	3.687		15400	4175	3	--	--	3	.74	.022					.022		
AS1	5		600		4400													
AS	27	3.976		16000	4025	3½	--	—	4	.64	.026					.026		
AT1	4		350		4010													
AT2	4		350		4010													
AT3	6		700		3565													
AT	27			16700	4200	1	--	--	1	.70	.007					.007		
AU1	4		350		4010													
AU2	4		350		4010													
AU3	6		700		3565													
AU	28	4.276		17400	4070	6	--	--	6	.64	.038					.038		
											TOTAL SYSTEM STATIC					5.64		
											LOSS THROUGH COLLECTOR					6.63		
exhaust stack	23½x 30½	4.977		17400	3495				10'	0.42	.04	EXHAUST STACK				0.04		
											TOTAL STATIC					12.31	IWG	
	FAN DATA		RPM	BHP														
	DESIGN		1026	49.1														
	OPERATE		1050	51.9														
MOTOR DATA			1750	50														



(Based on Standard Air of 0.075 lb per cu ft density flowing through average, clean, round, galvanized metal ducts having approximately 40 joints per 100 ft.) Caution: Do not extrapolate below chart.

Friction of Air in Straight Ducts for Volumes of 10 to 2000 Cfm



(Based on Standard Air of 0.075 lb per cu ft density flowing through average, clean, round, galvanized metal ducts having approximately 40 joints per 100 ft.)

Friction of Air in Straight Ducts for Volumes of 1000 to 100,000 Cfm

CRITERIA FOR SELECTING AND EVALUATING

ELECTROSTATIC PRECIPITATORS

By Yaacov Goland

INTRODUCTION

For various reasons, in recent years there has been a tendency among the writers of bid specifications to define the electrostatic precipitator in ever-increasing details. At one time, the application and its characteristics were the only information specified; today, it is more common than not to find in the specifications sizing criteria which establish a minimum precipitator size. In some specifications, there are also minimum criteria dealing with electrical sectionalization, mode of rapping and its level of acceleration response, and also materials and thickness of key elements, etc.

This paper will attempt to provide the purchaser with tools through which a better understanding of the design features submitted by the various vendors will be possible. Such understanding gained by the purchaser will, hopefully, help him accomplish two goals. On one hand, the purchaser's confidence that he obtained equipment suitable for his specific needs will be enhanced; while on the other hand, the need for infinitely detailed specifications will diminish, or at least be reduced.

However, if more detailed specifications are still considered necessary, then this presentation might provide the specifications writer with some insight into the precipitator's components and its design rationale.

It should be mentioned that this paper will deal with the precipitator design concept after its size (collecting surface area) and its electrical sectionalization have been established.

I. Precipitator's size as affected by certain design concepts.

A. High voltage frame and suspension system. Rigid frame style of high voltage electrodes will require wide gas passage, 11" or 12", to prevent sparking; similarly, longer length in the direction of the gas flow is required to suspend the frames. Wire and weight system will require about 9" or 10" gas passage width without any extra length for system suspension, but the precipitator height will be larger to accommodate the suspension system. In both cases, the electrical field strength will be the same (E/[G.P. width/2]), where E is in K.V., D.C.

B. Rapping system. Only when a flail hammer is utilized, will a rapping system be a factor on the casing size, since it will require room for the flail rotation and access (internal walkways) for its maintenance.

C. Hopper capacity and hopper minimum valley angle will affect precipitator height. Usually, hopper capacity is not a major factor since chamber width and one or two fields covered by one hopper will yield reasonable storage capacity (approximately twelve hours) providing the valley angle is 55° minimum. Note that the hopper capacity is a function of the collected dust density, and the tendency is to assume one density for stress purposes, and another for storage capacity (e.g. 80 Lb./Ft.^{3} and 40 Lb./Ft.^{3} respectively, for fly ash).

II. Precipitator adjustability and adaptability to various operating conditions.

Due to the many variables affecting the efficient operation of the electrostatic precipitator, some main system in the precipitator has to have a built-in capacity for adjustment. One should distinguish between two concepts of adjustability, that is, adjusting capability while the precipitator is "on line" versus adjusting capability only while the precipitator is "off line."

A. Automatic voltage control (A.V.C.).

This system is available today as a fully variable automatic system. Usually, one can adjust the voltage supplied to the precipitator, the rate of sparking (number of sparks per given period of time), the ramp rate (time required to recover to the voltage level prior to the sparking), and in some cases, the capability to distinguish between normal sparking and power arking. A power arc is defined as a sustained spark through an ionized channel that cannot be

A. (Continued)
blown clear by the gas stream. Extinguishing of a power arc requires the removal of high voltage. These systems are fully adjustable during precipitator operation in the automatic mode. A manual mode of operation is provided for maintenance or temporary variation.

The factors to consider in choosing A.V.C. are operational reliability, ease of maintenance, and response to changing precipitator conditions.

B. Rapping system. While the rapping system's purpose is to keep the collecting curtains and the high voltage electrodes clean of dust build-up, it should also be such that it will not cause dust reentrainment into the gas stream during the cleaning cycle. Since the exact analysis of the dust removal of the curtain is not yet available, the need for full adjustability in the field during actual operation is more pronounced. The adjustments to consider are:

1. Impact intensity (Ft. Lb.) to be varied for each field.

2. Impact frequency (number of impacts per second) of the rapper.

3. Length of rapping period (seconds), for the rapper.

4. Time between actuation of adjacent rappers.

5. Rapping sequence - what field will be rapped, at what time, or after which field.

6. Rapping coordination among chambers (not two outlet fields simultaneously).

7. Independent rapping of H.V. system from the collecting system.

C. Gas distribution. With a multichamber arrangement on one common ductwork (manifold at the inlet and the outlet), one should distinguish between two cases:

1. Gas distribution among chambers.

2. Distribution within a chamber.

C. (Continued)
Both subjects will be dealt with later; however, "on line" adjustability among chambers without interference with the distribution within a chamber is highly desired.

III. Precipitator operational reliability and maintainability.

A. The requirement of the precipitator is to operate with a certain minimum collection efficiency for a certain minimum length of time. It will not be attempted here to analyze in detail which design concept is more reliable; however, on a general basis, it stands to reason that no moving parts inside the precipitator is an advantage. At any rate, the main question should be: Once a failure occurs, what impact will it have on the continuation of the precipitator operation? The following is a list of additional questions by which practically all the precipitator systems could be evaluated:

1. What impact will a system failure (partial or entire) have on the collection efficiency?

2. Could the failure be corrected while the precipitator is "on line" or should the precipitator be taken "off line"?

3. What type of maintenance measures are required to keep the system operative (preventive maintenance, breakdown maintenance)?

4. What amount of redundency is built into the system, or could be incorporated into the system?

5. How accessible and convenient is the system for maintenance?

B. Based on past experience, the precipitator systems which are the major cause for failures are:

1. High voltage system and its controls.

2. Rapping system and its controls.

3. Hopper and hopper evacuation system.

B. (Continued)

In all cases, preventive maintenance is the key to reliable operation. Furthermore, in all cases the preventive maintenance does not involve replacement of parts as much as it involves proper operating procedures and inspection, specifically:

1. High voltage system and its controls

   a. Poor alignment of the high voltage electrode in respect to the collecting curtains will cause excessive sparking, will limit power supply to the field, and might ultimately end in the failure of the electrode. Other than wrong installation to begin with, there are two major factors which cause mis-alignment: First, dust build-up in the hopper to the extent of moving the collecting curtains against the H.V. frame, and bending it, and second, such magnitude of temperature gradient in the precipitator which will warp a system which hasn't enough flexibility built into it.

   b. Vulnerability of is the system to dust build-up on the supporting/electrical insulating components can cause grounding. Does the system subject the supporting insulator directly to the gas flow? Are positive methods built into the system to prevent such build-up and direct exposure of the insulators to the gas? (e.g. insulators compartment ventilating system, I.C.V.S.)

   c. Automatic voltage control. In this case, assuming available record of reliability in operation, the questions should be regarding ease of maintenance, mainly plug-in solid state cards, system check points for testing, and availability of indicating instruments. It is recommended to have primary current and voltage meters, secondary KVDC meters, D.C. Miliammeters, and sparking rate meters. The importance of the indicating instruments is mainly for provision of consistant and continuous data about the state of the whole precipitator system, as well as a base for comparing performance at various times and operating conditions.

B. (Continued)

2. Rapping system and its controls. The two main questions are probably, "How vulnerable are the rappers to the precipitator operating conditions (dust, temperature, corrosion)?" and "Can the rappers be maintained without taking the precipitator "off line"? As for the controls, desired capabilities will include "plug-in" type components, and a clear indication by the control system of where the failure occured and what its nature was (e.g. short circuit, open circuit). Furthermore, the control should not stop all rapping operation due to one rapper failure.

3. Hopper and hopper evacuation system

   a. Failure in evacuation of the dust from the hopper results in a severe affect on the precipitator collection efficiency. The dust build-up will eventually ground the high voltage system above that hopper. It then might cause bending of collecting curtains, bending of some type of H.V. electrodes, and also fusion of the dust will create clinkers which will, if nothing else, force precipitator shut-down, to allow hopper cleaning.

   b. Another type of failure of the evacuation system could be a leaking seal, which in a positive pressure evaculation system will cause dust re-entrainment into the gas stream with the end result being reduced efficiency.

   c. Hopper cold surface at the bottom might result in gas temperatures below the acid, or even the water vapor dewpoint. This not only causes severe corrosion, but also can be a cause for build-up of dust, which might lead to plugging.

   d. As far as the hopper itself, its proper design should include a dust level indicator which will sound an alarm about four to six hours before detrimental fillage (based on inlet dust load/ ACFM, collecting efficiency and hopper size). A hopper heating system is recommended, poke holes and vibrators are recommended as well, or at least target plates should be installed.

IV. Connected load and utilized load

The major potential power consumption are in the following order: transformer/rectifier (T/R) power supply to high voltage system about 65%, insulators compartment heating and ventilation system about 18%, hopper heating system about 10%, and the rest is for controls, lighting, etc. (not including air conditioning). With proper instrumentation and control system design, the insulator compartment ventilating system can operate such that only during start-up and shut-down period will it consume all its rated power. During normal operation, only a fraction of it will be used. Similarly, the hopper heating system could, under certain operating conditions, consume only a small fraction of its rated power, mostly used during start-up and shut-down periods.

Although the T/R sets alone have a reasonably high power factor, about 90%, the reactive components used for control as wave shaping lower the overall power factor appreciably. This effect can be minimized by specifying properly chosen taps on the T/R set.

V. Materials of construction

When dealing with dry precipitators, as this paper mainly does, it is conventional to assume that chemical corrosion will not be a problem. If chemical corrosion might present a problem, the conventional solution is to elevate the temperature sufficiently to overcome the corrosion. In some cases, a shorter precipitator life should be estimated to begin with.

The stress analysis coupled with cost optimization form the decisive design criteria for material selection. There are, however, some considerations which affect not only the material itself, but also the calculation process. These are:

A. Operating at high temperatures up to 850°F.

B. Operating at low temperatures, about 300°F to 400°F, but with frequent excursions in the range of 600°F and 700°F.

C. Operating at cycling loads.

These conditions introduce three main factors: creep due to high operating temperatures, oxidation due to high operating temperatures, and fatigue due to cycling mode of operation. Of the three, fatigue is the least

C. (Continued)
important, since even if the load cycling will take place twice twice a day for 30 years, the total number of cycles (approximately 21,000) is still low.

It should be noted that recently the concept of operating a system with daily and/or weekend complete shut-down was introduced. This mode of operation presents, in addition to the fatigue problem, the problem of corrosion, unless special bottling up procedures are initiated, preventing the system temperature from going below the acid dew point.

VI. Evaluating options. The main questions when evaluating options should be:

A. Will the optional equipment improve operation reliability (e.g. stand-by I.C.V.S.)?

B. Will it help in getting more trouble-free operation and longer life for the equipment (e.g. hopper heating, level indicators)?

C. Will it make maintenance easier (e.g. quick-opening, instead of bolted doors, T/R removal system)?

D. Will it provide better protection to personnel and equipment (e.g. weather enclosure, ventilated)?

E. Finally, is the optional equipment essential to the precipitator operation? If it is, it should not have been optional to begin with, but part of the basic package.

VII. Ductwork

As is true with just about any other subject dealt with in this paper, a full paper could have been written (and, in fact, many papers were) about ductwork design. However, the following are some basic questions which probably carry the major importance in evaluating a precipitator and its ductwork system even after assuming that gas distribution at the precipitator's very inlet is dealt with properly during the design.

A. Did the pressure drop calculation take into consideration internal bracing in the ductwork? This can account for up to 20% of the total.

VII. (Continued)

B. Was the velocity in the ductwork calculated to deal with dust build-up associated with operating at reduced load, or even build-up during normal operation?

C. Is there a built-in capability (in multi-chambers manifold arrangement) to adjust the flow among chambers during precipitator operation?

D. Was the cost of the energy to overcome the pressure drop evaluated for the expected life of the precipitator?

VIII. Temperature gradient - insulation and casing leakages.

Theoretically, the temperature drop of the gases moving through a properly insulated precipitator should be negligible. For 750°F inlet gas temperature, the temperature drop due to heat loss through the walls, top and hoppers, including heat loss for heating up the air from the ICVS, should be about 8°F. Generally, the insulation thickness is based on data given by the insulation manufacturer. This data is usually for vertically oriented sample board at ≈ 70°F ambient temperature with zero wind. Then, aiming for approximately 115°F cold surface temperature, the thickness is determined for various temperatures at the hot side of the sample board. Utilizing this "catalog" thickness for actual calculations, assuming average wind velocity typical to the job site, and assuming worst low ambient temperature, the true ΔT calculated will be obtained. It will be about 5°F. This is mostly due to the low gas velocity inside the precipitator, which does not promote good heat transfer by forced convection, and the short retention time of the gas in the casing.

There are two main factors in avoiding high ΔT:

A. Insulation - installation quality.

1. Was thermal expansion taken into consideration? (Avoiding gaps in the insulation layers.)

2. In case of insulation between reinforcing members, was the reinforcing insulated properly itself to prevent cooling fins effect?

3. Is there a chimney effect - defined as vertical free passage between the hot wall and the insulation, allowing heat loss by natural convection?

VIII. (Continued)

B. Leakages into system by ambient air. A ΔT of about 40°F could be caused on 750°F flow, at about 10" V.W.C. negative operating pressure if the total open area due to improperly sealed casing, is about 1.0 $ft.^2$. Temperature drop of this magnitude on about 250,000 ACFM flow is equivalent to about 1.5 MW in energy required for heating the air flow through an air preheater. Therefore, it is recommended to have very tight inspection on welding quality, even to the extent of performing pressure tests on the whole system. Possible criterias for such pressure tests are: allowable leakage at design pressure to be about .05% of the enclosed system volume in cubic feet per minute corrected to standard conditions. This test has to be done, of course, prior to the applying of the insulation, so that the opening could be seal welded. This test might be preferred over holding pressure for a given period of time, since it directly indicates the leakage rate; besides, with a system as large and complex as an electrostatic precipitator, it is very difficult and expensive to seal perfectly all the openings which are not normally closed.

CONCLUSIONS

Consideration of the criteria and discussion provided here, should provide the reader of the paper first, when he writes the bid specifications, and second when he evaluates the response, with the capability to analyze what he expects to buy, and what was actually offered.

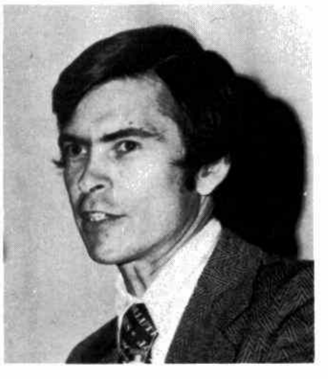
ACKNOWLEDGEMENT

The writer wishes to thank both W. Carney - Senior Electrical Engineer, and R. Sidaway - Chief Mechanical Engineer, in Western Precipitation for their review and constructive comments on this paper.

SESSION III

Session Chairman
D. A. McTavish
Regional Director
Southwestern Region
Ministry of the Environment
London, Ontario

Effluent Treatment at the Sudbury Processing Complex of INCO Limited
E. C. Nevala
Supervisor, Utilities Operations
Environmental Control Department
Ontario Division, INCO Limited, Sudbury, Ontario



Design and Operation of an Activated Carbon Wastewater Pretreatment System
K. C. Bradley
Senior Chemist — Pollution Control
Uniroyal Chemical
Division of Uniroyal Limited, Elmira, Ontario

Operation of a Cold Mill Waste Treatment Plant
G. H. Rupay
General Foreman, Pollution and Monitoring
Dominion Foundries and Steel Co. Limited
Hamilton, Ontario

Development, Start-up and Operation of a Bio-Oxidation Treatment Facility for a High Saline Wastewater Stream
E. A. Sommers
Superintendent Bio-Oxidation
Dow Chemical of Canada Limited,
Sarnia, Ontario

AQUEOUS EFFLUENT TREATMENT AT THE

SUDBURY PROCESSING COMPLEX OF INCO LIMITED

E. C. NEVALA

INTRODUCTION

The discovery of copper-nickel sulphides in the Sudbury area during the 1880's by Canadian Pacific Railway construction crews led to the development of the most important nickel producing area in the world. Inco Limited and its predecessors have played the major role in this resource development. In 1966 an expansion program was launched to increase productive capability to 17 440 tonnes of nickel annually. This expansion program required the tailings disposal facilities be enlarged so that additional ore could be processed.

In 1970 a consulting firm was engaged to conduct the necessary studies to outline recommendations for the development of new tailings disposal facilities at Copper Cliff, Ontario.

The terms of reference established and the scope of the study deliniated the following:

1. Determine future volume and character of the wastes to be disposed.

2. Locate possible disposal sites and evaluate them in respect to cost, environmental and socioeconomic effects.

3. Recommend the optimal disposal area and develop implementation proposals and costing.

4. Recommend future disposal methods.

Very early it became clear that the scope must be expanded to provide a comprehensive study. Therefore, among other pertinent items the following was included:

> "the optimum point of disposal of waste mine drainage water to either of".

(a) the tailing disposal area or,
(b) the environment.

PROJECT DEVELOPMENT

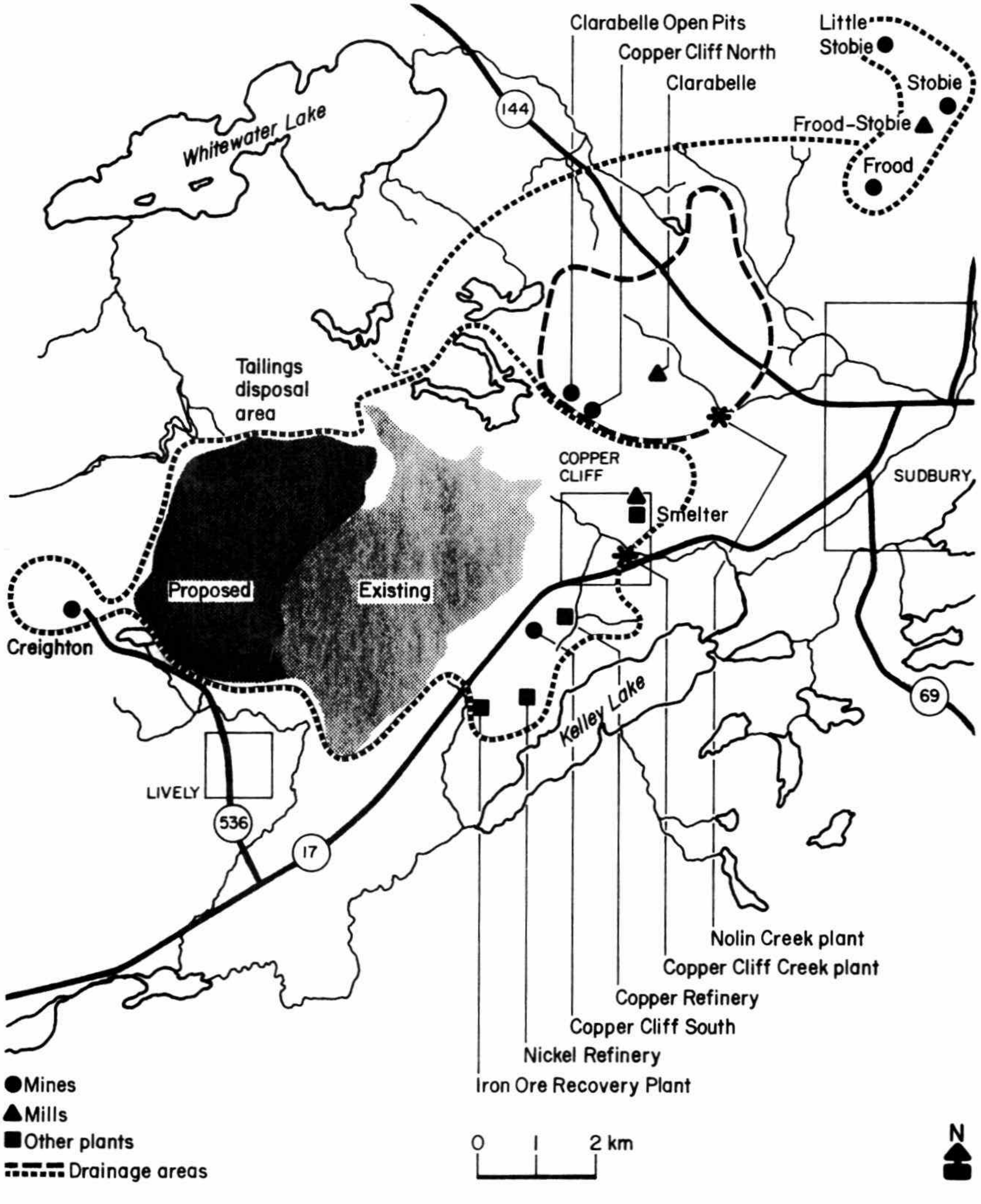
As the project study investigated the various waste waters: such as urban run-off, mine waste waters, plant run-off and tailing decant, a panorama for the centralization of treatment emerged.

The apparent and most appropriate location for the expanded tailing disposal facility became an extension of our existing disposal site. In taking this course, the entire area employed in tailing disposal could then be gravity drained to a common treatment plant as well as providing a suitable location for a water recycling system. Therefore it was decided to locate the treatment plant on Copper Cliff Creek.

The drainage area served by this plant is some 33.5 km^2 encompassing the effluents from the Copper Cliff Smelter, Iron Ore Recovery Plant, Copper Cliff Copper Refinery, Copper Cliff tailing disposal area, Copper Cliff North Mine, Copper Cliff South Mine, the Frood-Stobie Mine complex and the Creighton Mine complex.

Figure I

Wastewater treatment plant locations



Kelley Lake has been the receptor of untreated urban and industrial wastes for almost a century. With the advent of the intended treatment facility and the Sudbury sewage treatment plant, it was considered desirable to include in the investigation treatment of the Nolin Creek, a second tributary feeding Kelley Lake.

The flow in Nolin Creek, primarily the natural run-off from 6.5 km^2 is subject to extreme flow variations ranging from zero to 909 m^3/h. The natural run-off is high in heavy metals leached from outcroppings in the vicinity of the discovery area.

In order to further reduce the heavy metal loading of Kelley Lake it was decided to provide a treatment facility for Nolin Creek.

These two treatment plants were included in the presentation to the Ontario Water Resources Commission and, following the public hearing in 1972, approval was granted to proceed with the enlargement of the tailing disposal area and the construction of two treatment plants.

Flow studies of the Copper Cliff and Nolin Creeks indicated that plants having a capacity of 228 000 m^3/d and 26 400 m^3/d respectively could treat the effluents and run-off except during short periods of abnormally high flows. (Figure 1)

LABORATORY AND PILOT PLANT STUDIES

The search for an effective method to treat Copper Cliff Creek water was started in the summer of 1971. Considerable

testwork was carried out in the laboratory, and during September and October 1971 a pilot plant was operated to establish a suitable process and to provide the basic data required for the design of a treatment plant.

Initial examination of the problem led quickly to the conclusion that the Copper Cliff Creek water should be treated in principal by a process of neutralization and clarification.

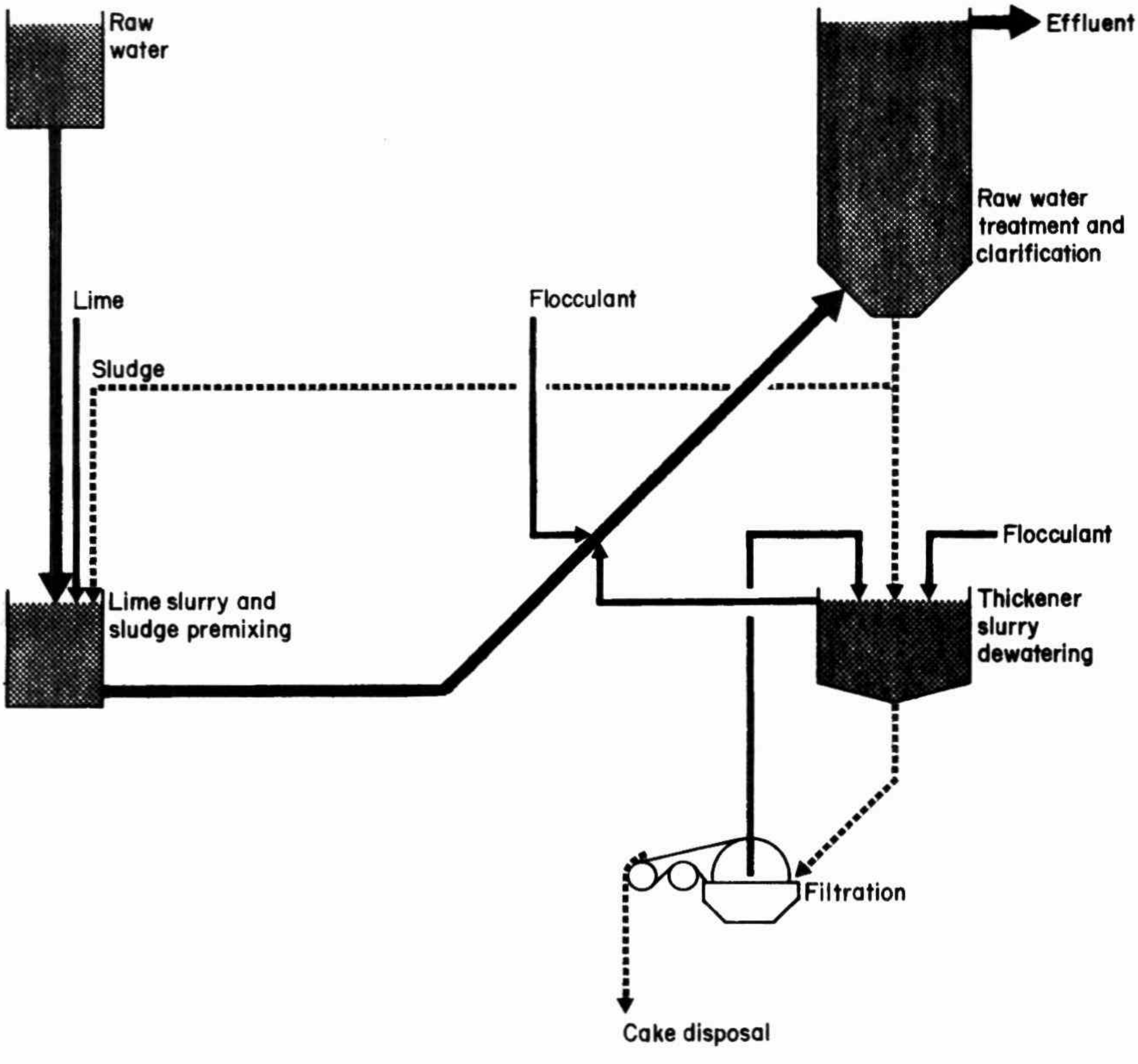
The process chosen for Copper Cliff Creek water was evaluated in the pilot plant schematically shown in Figure 2. Altogether 4731 m^3 of Copper Cliff Creek water, at 10 - 21^oC were treated. The floc blanket previously developed was left in the clarifier to obtain treatment results for Copper Cliff Creek water without undue delay.

Continuous operation of the pilot plant for seven weeks led to the following conclusions......

1. Treatment of the raw Copper Cliff Creek water with a 5 to 6 percent lime slurry raised the pH into the range of 9 to 10. During the last two weeks of the campaign optimal conditions prevailed and the averaged purification and clarification results obtained were as follows......

pH	8.8 - 9.2
Total nickel	0.5 mg/l
copper	0.2 mg/l
iron	0.5 mg/l
Suspended Solids	5.0 mg/l

Figure 2
Wastewater treatment pilot plant



The effluent quality achieved during continuous pilot plant operation was superior to the O.W.R.C. requirements for such streams at the time of testing.

2. In order to raise the pH of the feed water and precipitate the heavy metals, copper, nickel and iron, 0.096 kg CaO (in slurry form) was consumed on average for one cubic metre of feed water. The lime consumption in the pilot plant ranged from 0.066 to 0.120 kg/m^3 feed water.

3. Satisfactory clarification was obtained when anionic polyelectrolytes were used to aid the flocculation of the suspended solids. Jar tests indicated that Separan MG 200 and Separan MG 700 at a dosage of 0.7 mg/l or Alfloc 4154 at 2.0 mg/l would give suitable floc size, settling rates, and supernatant clarity. Alfloc 4154 was employed during the pilot run at 3 mg/l to compensate for floc damage in the centifugal pumps. The Separan products were not available in sufficient quantity for pilot plant evaluation; however, Separan MG 200 at 1.0 mg/l was recommended for full scale plant operation. The polyelectrolyte additions were made as a 0.5 percent solution.

4. It was found that the density of the clarifier underflow sludge could be increased by recycling part of the sludge to the feed preparation stage. As required, lime would be added to the recycled sludge which then would be fed to raw Copper Cliff Creek water in the reaction tank. The ratios of the solids in recycled sludge to raw water solids varied in the range of 13:1 to 21:1. For plant design a recycle ratio of 15:1 was recommended.

During the design stage of the treatment plant it was felt that increasing the density of the clarifier underflow sludge was not of great advantage because it was planned to pump the relatively small amount of solids produced as a thin slurry to the Copper Cliff Mill area.

5. A retention time of three minutes for the reaction of the lime slurry with the raw water in the mix tank was considered adequate.

6. During the last two weeks of the campaign the clarifier was operated at or near optimal throughput rates, and during this period the clarifier rise rate ranged from 4.15 to 5.62 m/h. The average rate of 5.13 m/h at 16^{o}C was suggested as a basis for design.

7. Excellent clarity was achieved with massive recirculation of the flocculated solids in the reaction chamber of the clarifier. However, this mode of operation made control over the blanket of flocculated solids more difficult whenever operation without recycle of underflow solids was attempted.

The salient points of the process that emerged from the pilot test campaign can be summarized as follows.......

Treat raw Copper Cliff Creek water for about three minutes with lime slurry to obtain a pH of 9.4 $\pm$ .2 in the clarifier overflow. Use anionic flocculants at a dosage of about 1.0 mg/l to develop a blanket of flocculated solids.

Employ a flocculating turbine in the clarifier reaction stack for improved clarification. Expect a sludge production of 0.072 kg (as dry solids) per cubic metre of water treated. Consider a clarifier rise rate of not more than 5.13 m/h.

In the fall of 1972 laboratory tests were carried out with Nolin Creek water to provide a process for the projected treatment plant. In contrast to Copper Cliff Creek water, the Nolin Creek water carries a higher level of dissolved heavy metals. At the time of the test work, the combined concentrations of copper, nickel and iron in solution ranged from 54 to 74 mg/l on dry days, but increased to 119 to 159 mg/l following rain. The content of suspended solids in the raw water was about the same as found in Copper Cliff Creek water, subject to the same sharp increases after rain storms and during spring run-off.

The lime addition required to elevate the pH of the raw water from 4.1 to a level of 9.4 ± 0.2 with a five percent slurry averaged 0.17 kg CaO per cubic metre of raw water with variations between minimal and maximal requirements of 0.12 and 0.24 kg. Standard jar tests indicated that good floc size, fast settling and satisfactory supernatant clarity could be obtained when 0.5 mg/l of an anionic polyelectrolyte such as Separan MG 200 was used. A suitable clarifier rise rate could not be determined accurately in the laboratory, however the similarities in the composition of Nolin Creek water and a synthetic waste water, for which a clarifier rise rate had been established in earlier pilot plant work, permitted a specification of 2.20 m/h at 24°C for the clarifier of the Nolin Creek Water Treatment plant. In view of the strong

similarity of these two waters, the same process was recommended for the Nolin Creek treatment plant. The average sludge production for Nolin Creek was determined at 0.59 kg dry solids per cubic metre of raw water. Originally, sludge recycle for lime sludge mixing prior to reaction with the raw water was recommended for Nolin Creek as it had been for Copper Cliff Creek, however increased clarifier underflow sludge density was not seen to be of great importance because it was intended to return the heavy metal bearing clarifier sludge via a holding pond to the Copper Cliff Smelter for recovery of the metal values. The laboratory work demonstrated that the treatment process recommended for Nolin Creek water would succeed in attaining a discharge water quality superior to the OWRC standards of the day.

DESIGN

The waste water treatment facilities were based on conceptual design and on performance specifications prepared by Inco Limited. The contractor was responsible for the detailed engineering, equipment selection and construction.

Naturally, some aspects of the project required considerably more investigation and thought than others. Chief among the former were the type of foundations needed and the type of construction of the two 41 m diameter by 7 m clarifiers planned for Copper Cliff Creek.

Detailed soil analysis indicated that the underlying soil was an unstable clay having a low load bearing value and that ground water could be a significant problem in any excavation.

Accordingly, the decision was made that the clarifiers should be pile supported at grade to avoid excavation, and that excavation for the pumphouse be sheet steel piled with provision for extensive dewatering.

The decision to construct the clarifiers at grade allowed the sludge to be extracted by gravity rather than by pumping as was originally envisaged.

The next major decision to be made was the material and type of construction for the clarifiers. For the walls, steel, reinforced concrete and post-tensioned reinforced concrete were considered, analyzed and costed. Ultimately, the decision was made to employ, post-tensioned reinforced concrete walls, with reinforced concrete base slabs, sludge wells and skirts for reasons of appearance, thermal conductivity and economics. The post-tensioning system chosen employed cables in PVC ducts embedded in the concrete walls, each cable extending through 180° and staggered in successive rows.

All of the previously described decisions were reached, in principle, during the preparation of the contractor's proposal. Thus, when the contract was awarded, a significant amount of basic design had been completed and detail design could proceed immediately.

Throughout the design and construction of the works, the closest possible liaison was maintained. This allowed Inco to check compliance with their requirements at every stage, thus expediting approvals, and to minimize changes to the completed work. This close co-operation was of significant value to both the contractor and the owner.

CONSTRUCTION

Notification of award was made on May 24, 1974. Construction forces arrived on site June 10th and by July 12th site grading was complete, construction camp established and structural pile driving completed by August 28th.

In all, 334 reinforced concrete 90 tonne end bearing piles were driven to bedrock with a total cut-off length of 6 625 m. One hundred and fifty piles were required under each clarifier to support the established total weight of approximately 12 700 tonnes. Thirty of the remaining 34 piles were driven to support the 18 m x 15 m pumphouse/control building and four were required to support the 6 m diameter by 6 m high lime slurry storage tank. Other ancillary structures, such as the substation and the creek diversion weir were built on spread reinforced concrete footings.

The elapsed time from the awarding of the contract to the start of operation was 76 weeks.

PLANT OPERATION

Copper Cliff Creek Waste Water Treatment Plant (Figure 3)

Intake

A Cepoletti weir, constructed across the Copper Cliff Creek retains and diverts all flows up to 9 500 m^3/h to the Copper Cliff Creek waste water treatment plant. Excess flow bypasses the plant and overflows the weir. Raw water is drawn through two 2.7 m wide intake channels equipped with bar screens at 7.6 mm openings. Located downstream and within the plant, two motor driven travelling water screens remove remaining debris on a 1 cm cloth.

Three, vertical, 250 HP single stage pumps rated at 3 400 m^3/h at 15 m TDH pump the raw water through a 0.9 m diameter header, common to both clarifiers. The flow to the clarifier is automically controlled by a raw water well level signal.

Clarifiers

The 41 m diameter clarifiers having a side wall depth of 7 m, centre depth of 8.5 m sludge raking system, feature internal sludge recirculation in the centre zone. The raw water is premixed with slaked lime and the polymer is added to the clarifier feed lines. Thorough mixing takes place with previously formed floc in the reaction zones.

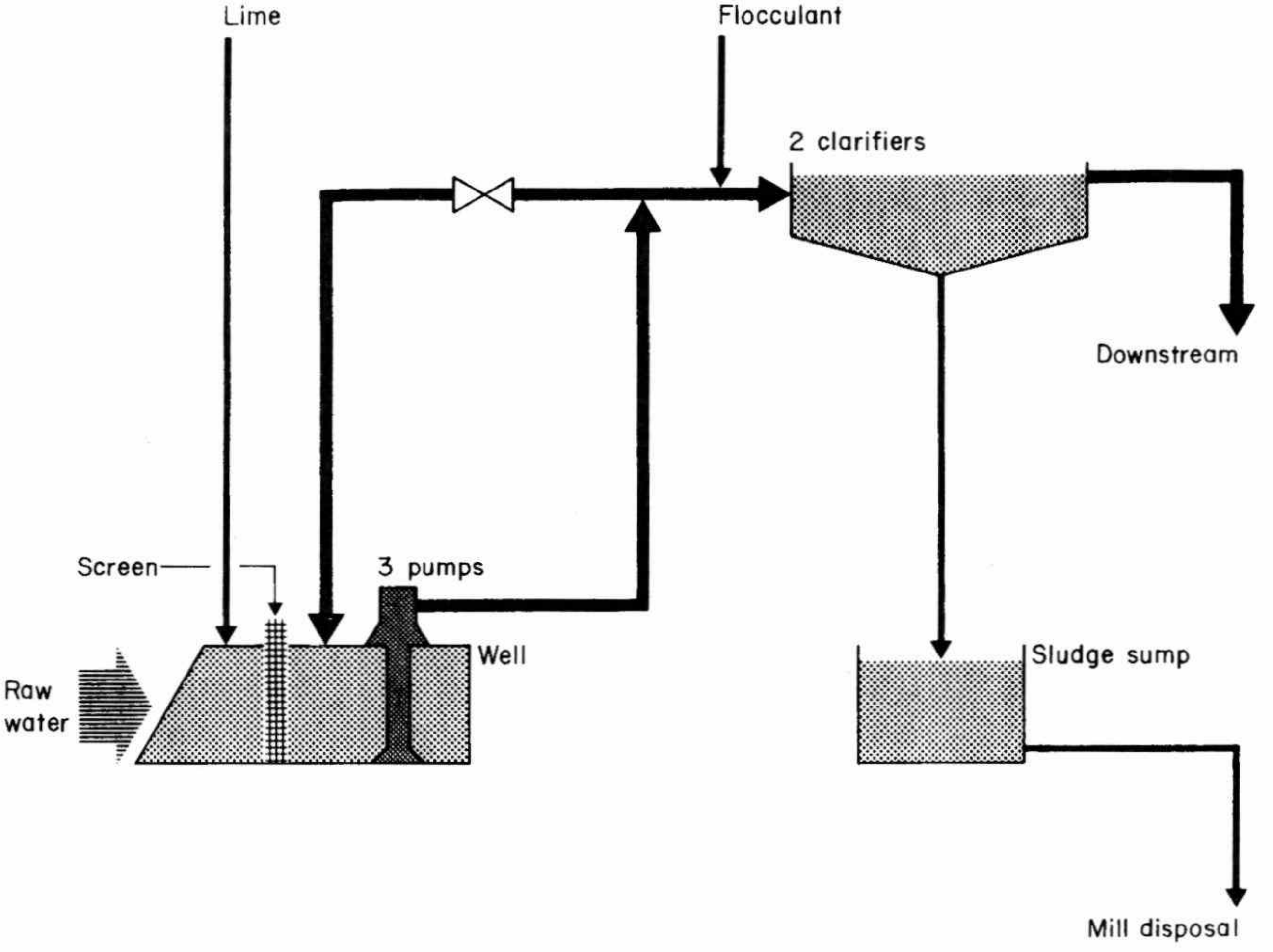
The sludge thus formed provides a filter blanket through which the water must pass to discharge through sixteen 0.5 m submerged radial launders. The treated effluent is then returned to the natural water course with a portion recycled within the plant for process use.

The sludge consisting of metal hydroxides and silt is raked to the centre cone for gravity withdrawal on a manually adjusted sequence to correspond with sludge depth and clarifier torque. The metal content of the sludge determines its destination: Copper Cliff Creek plant sludge to the tailings area, Nolin Creek plant sludge to the smelter for recovery.

Effect of Temperature

During severe cold, a low pressure air diffuser provides an air curtain at the periphery of the draft tube to prevent ice bridging. At the Copper Cliff Creek plant use of air curtains were limited to periods of extreme cold only. At the Nolin Creek

Figure 3
Copper Cliff Creek wastewater treatment plant



plant however, the air curtain is employed continuously because of the low (200 m^3/h) flow rate.

Alternative methods, such as floating logs or styrofoam slabs will be investigated because the air curtain has a tendancy to inhibit settling in the quiescent zone.

During periods of hot weather, the Nolin Creek water temperature may increase sharply from 15°C to 24°C in 3-4 hours causing convection currents within the clarifier which may result in additional suspended solids in the effluent. This problem usually appears on sunny days and at low flow rates (200 - 400 m^3/h) late in the afternoon lasting until midnight.

pH Control

Slaked lime (25% CaO by weight) is bled from a pressure loop, by pneumatically regulated Fisher-Porter pinch valves, to neutralize the incoming water to a pH range of 9.4 $\pm$ 0.2. PH values above 9.8 resulted in excessive suspended solids in the effluent. At low pH the nickel does not completely precipitate. Provision was made in the original design to adjust pH in two stages, however, it has been found that precipitation of metals must be complete prior to the addition of a polyelectrolyte.

Jar studies indicate that the best settling floc can be formed by allowing the lime 3-4 minutes to complete neutralization before adding a polyelectrolyte. Plant layout does not permit this extended retention time, however this has prompted the introduction of the lime slurry as early as possible into the system. Following a 10:1 dilution, lime slurry is evenly split and fed midstream to each of the two intake channels ahead of the inlet screens for optimal mixing.

Lime addition through a modulating rubber pinch valve is automatically controlled by pH measurement of the clarifier influent. Preliminary testwork carried out to minimize pH fluctuation has shown the pneumatically actuated ball valve to be more effective.

Rise Rates

The design rise rate of 5.13 m/h at peak flows of 4 800 m^3/h have been reached without significant increase in suspended solids of the effluent at the Copper Cliff Creek plant. However, due to changing raw water characteristics at the Nolin Creek plant and resultant sludge variations, operation at the design flow rate is not always possible. Generally a rise rate of 2.44 m/h cannot be exceeded without excessive carryover of solids into the overflow.

Flocculant Addition

Polyelectrolyte performance can be the source of opinions being often at variance. At the Copper Cliff plant preference is given to a slightly anionic polymer in liquid form, which has proven to be as effective as the dry material. The added benefits, such as ease of handling, and feeding, and the low risk of spillage generally outweigh the advantage of lower consumption rate of the dry powder. Nevertheless, the evaluation of flocculants must continue to be an ongoing programme to keep abreast with the latest developments and to determine the most cost effective polyelectrolyte.

Nolin Creek Waste Water Plant

The two treatment facilities, because of their operating similarity, are basically operated from the Copper Cliff plant. This is achieved by the telemetry of the main operating parameters to the Copper Cliff control console where the shift operator can monitor the operation continually; this minimizes staff while maximizing operating surveillance.

TREATMENT RESULTS

The effluent quality achieved in the Copper Cliff Creek waste water treatment plant during the first year of operation is given in the form of semiannual averages as follows...

	mg/l						
1976	pH	Tot Cu	Tot Ni	Diss Ni	Tot Fe	Diss Fe	Suspended Solids
Jan-Jun	9.5	0.2	0.6	0.3	1.2	0.9	15
Jul-Dec	9.5	0.1	0.4	0.2	0.8	0.1	11
Objectives	6.5 - 9.5	0.2	0.5		0.5		15

In comparison, the average quality of the raw water treated in the plant during 1976 was ....

	6.6	0.3	2.0	1.8	5.3	1.1	25

Minor modifications to the plant equipment and the operating mode have contributed to better performance and further improvement is expected for 1977.

Operation of the Nolin Creek waste water treatment plant produced in general acceptable results in 1976.

CONCLUSION

In close cooperation with all parties having an interest in our environment and productive viability a satisfactory solution was found to treat the combined urban and industrial waste waters at the Sudbury processing complex of Inco Limited. The operation of the well designed and constructed treatment facilities has shown during the first year of operation that a high quality effluent can be produced by the chosen process of neutralization and clarification.

APPENDIX I

VITAL STATISTICS

Copper Cliff Creek Waste Water Treatment Plant

The following is a summary of the major components and quantities required to complete the project........

Clarifiers: (upflow, solids contact reactor type)

- two, each 41 m x 7 m SWD
- max. treatment rate 9 500 m^3/h
- 126 m/d rise rate
- Solids recycle ratio 15:1 maximum

Raw Water Pumps:

- Three 3 410 m^3/h @ 15 m TDH, 250 HP
- Single stage vertical circulating turbine.

Lime System:

Tank:

-Storage 6 m dia. x 6 m high insulated, heat-traced outdoor tank, 170 m^3, 25% slurry.

Agitator:

- (complete suspension) 15 HP, 45 RPM, 1.7 m dia. impeller.

Pumps:

- Two each 15 m^3/h @ 23 m TDH, 1 750 RPM, 5 HP rubber-lined slurry pumps.

Consumption:

- Design average 96 g CaO/m^3 raw water (raise pH to 9.3 - 9.5)

Polyelectrolyte:

- Type - Nonionic to moderate anionic.

Design Feed Rate:

-0.5 mg/l

Feed/Wetting:

-0.12 m^3/h dry, 38 l/min water wetting
4.6m^3/h transfer/dilution.

Age/Mix:

- 11.4 m^3, 2.4 m x 2.4 m high FRP plastic tank 10 HP, 84 RPM, 3 blade 0.8 m dia. impeller.

Transfer:

- Positive displacement pump, 5 HP, 1 145 RPM

Storage:

- 18.9 m^3, 3.1m dia. x 3.4 m high, FRP tank

Metering

- 3 metering pumps, duplex head, 1.6 m^3/h, 3 HP, 1 750 RPM, automatic capacity adjustment.

Sludge: - Design production (per Pilot Plant Studies) 95.8 m^3

Recycle:

- Ratio 15:1, 6% of raw water feed volume.

Pumping:

- Two pumps, each 46 m^3/h @ 50 m TDH horizontal end section centrifugal, 25 HP, 1 750 RPM.

Disposal:

- Normally: to mill tailing disposal system
- Emergency: to smelter pond.

Service Water:

- clarifier effluent for lime and polyelectrolyte dilution/injection, cleaning, flushing, etc., two pumps, each 109.1 m^3/h @ 60 m TDH, horizontal split-case centrifugal, 50 HP, 1 750 RPM.

Raw Water Screens:

- Two each 10 230 m^3/h, 2.4 m wide, 9.5 mm SS. cloth screen, 3 m/min travel speed, 1.5 HP.

Low Pressure Air:

- Clarifier anti-icing air curtains 14 m^3/min @ 20 kPa, two compressors, 250 dm^3/s at 35 kPa, 20 HP.

Instrumentation:

- Pneumatic/electronic in a conventional mixture
- 2 compressors, each 16.5 dm^3/s , 690 kPa, 10 HP 1 750 RPM.
- Air dryer - 19 dm^3/s @ 690 kPa, c/w pre-filter and after-filter, 100 W.
- Automatic continuous measurement and recording of raw water, process and effluent pH, effluent ammonia, effluent suspended solids, effluent temperature, raw water flow.
- Lime addition is automatically controlled by the pH of raw water and/or clarifier reaction zone.
- Polyelectrolyte addition is automatically controlled at a set rate by integration of measured raw water flow.
- Raw water flow to each clarifier is measured by 0.6 m magnetic flow meters.

APPENDIX II

Nolin Creek Waste Water Treatment Plant

Raw Water Screens:

- 1 Screen of 1 700 m^3/h capacity.
- 1.2 m wide 9.5 mm SS cloth screen
- Travel speed of 1.2 m/min. 10 HP driver

Raw Water Pump:

- 3 pumps of 580 m^3/h @ 15.2 m TDH
- 50 HP single stage vertical turbines

Clarifier:

- Upflow solids contact reactor type
- 1 clarifier of 24.4 m Dia. x 5.2 m S.D.
- maximum treatment capacity of 1 100 m^3/h
- rise ratio of 2.2 m/h
- solids recycle ratio of 15:1 maximum

Lime System:

Storage:

- 72 m^3 capacity (25% slurry)
- 4.6 m I.D. x 6.4 m wall height
- insolated, heat traced outdoor tank

Agitator

- 3 HP, 68 RPM output
- complete suspension turbine

Pumps:

- 2 pumps of 11.4 m^3/h @ 18.3 m TDH
- 3 HP @ 1800 RPM
- Rubber lined slurry pump

Consumption:

- 1.0 kg CaO/m^3 raw water to raise pH to 9.4 $\pm$ 0.2

Polyelectrolyte:

- Type - nonionic to moderate ionic
- Design feed rate - 0.5 mg/l

Polymer Feed/Wetting:

- 0.12 m^3/h dry polymer feed rate
- 38 l/min water spray (wetting)
- 4.6 m^3/h transfer & dilution

Age/Mix

- 2.3 m^3 capacity (FRP construction)
- Dimensions 1.5 m dia. x 1.5 m height
- Impeller 2 HP
- 84 RPM output
- 4 blades each 9.5 m dia.

Transfer:

- Gravity feed through a 10 cm valve.

Storage:

- Capacity 4.6 m^3
- Dimensions 1.8 m dia. x 2.0 m height
- Material - FRP

Metering:

- 2 metering pumps (duplex head)
- capacity of 0.8 m^3/h
- 1 HP x 1 750 RPM
- automatic capacity adjustment.

Sludge: Production:

- 0.6 kg·dry solids /m^3 raw water

Pumps:

- 2 pumps or 100 m^3/h @ 67 m TDH
- 3 stage pumps of 50 H P @ 3 450 RPM

Disposal:

- To upper smelter ponds for reclamation
- 2 lines (one normal + one emergency)

Service Water:

- 2 pumps of 100 m^3/h @ 67 m TDH
- 50 H P @ 1 775 RPM
- Used in Plant for lime dilution, cleaning & flushing

Air Blowers:

- 1 compressor 120 dm^3/s @ 34.47 kPa
- 20 HP @ 1 755 RPM
- Used as deicing air for clarifier

Instrumentation:

- Conventional mixture of pneumatic/electronic
- 2 compressors - 15 dm^3/s @ 690 kPa
  - 20 HP @ 1 750 RPM
- Heat reactivated dryer - 15 dm^3/s @ 690 kPa
  - Silica gel Desiccant
- automatic, continuous measurement and recording of raw water, process and effluent pH, effluent NH_3 and S.S., effluent temperature and raw water flow.
- lime addition controlled automatically by the raw water well pH.

- Polymer addition controlled automatically at a set rate by integration with the raw water flow.
- Raw water to clarifier measured by 0.5 m magnetic flow meter.

OPERATION
of a
COLD MILL WASTE TREATMENT PLANT

G. H. Rupay

INTRODUCTION

Dominion Foundries and Steel, Limited of Hamilton, Ontario is a fully integrated steel company producing about three million ingot tons annually. The main products are cold rolled flat plate and electrolytic tin plate.

A variety of chemicals and oils are used to produce these products. Hydrochloric acid is used on three pickling lines. Caustic based cleaners are used on two cleaning lines and the cleaning sections of the tower anneal and electrolytic tinning lines. Also, on the electrolytic tinning lines, sodium dichromate is applied to protect the tin plate from corrosion and sulphuric acid is used in the pickling section. Oil emulsions are used as lubricants on eight cold rolling mills and several roll grinding machines.

In the past the wastes from these operations were discharged to storm sewers which eventually flowed into the Hamilton Bay. Adjustments were made to control the pH and an oil boom and skimming mechanism removed most of the floating oil as it entered the bay.

As people became more pollution concious, discharges such as these became unacceptable. In the early 70's, Dofasco began work on a cold mill waste water treatment plant and collection system.

The original concept was a centrally located treatment plant designed to:

1) treat waste oil emulsions and recover oil suitable for burning as a bunker oil substitute,
2) treat acidic and alkaline solutions by neutralization and clarification, and
3) treat dilute solutions of sodium dichromate using an ion exchange system, recycling the demineralized water and regenerated sodium dichromate.

Although the plant contains three sections, effluents from all sections flow through a clarifier and are discharged to the City of Hamilton sanitary sewer for further treatment at the municipal treatment plant.

The design flowrate is 2000 USGPM and the requirements for discharge to the sanitary sewer are:

	MAXIMUM LIMIT OR RANGE
TEMPERATURE	LESS THAN 150°F
OILS	100 mg/l
pH	5.5 – 9.5
SUSPENDED SOLIDS	350 mg/l
BIOCHEMICAL OXYGEN DEMAND	300 mg/l
CHROMIUM	3 mg/l

The plant was commissioned in September of 1974 but numerous problems with equipment and the process have been experienced.

This paper describes the plant process and equipment, discusses some of the problems, outlines the proposed improvements and gives a brief summary of the economics of cold mill waste water treatment by this method.

PLANT LOCATION

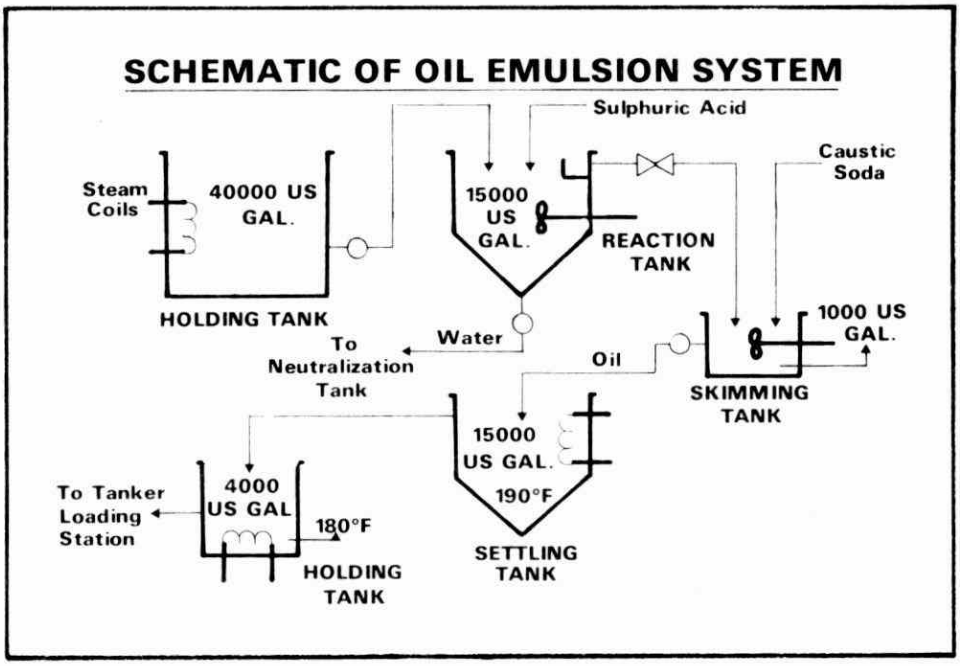
Dofasco's cold rolling, cleaning, pickling and tinning operations cover a wide area. The treatment plant is located above Ottawa Street in a three building complex that also contains a hydrochloric acid regeneration plant and a hot mill waste water treatment plant. Cold mill wastes are collected from about thirty locations throughout the plant.

PLANT DESCRIPTION

The cold mill waste water treatment plant consists of three sections as outlined in the original design concept.

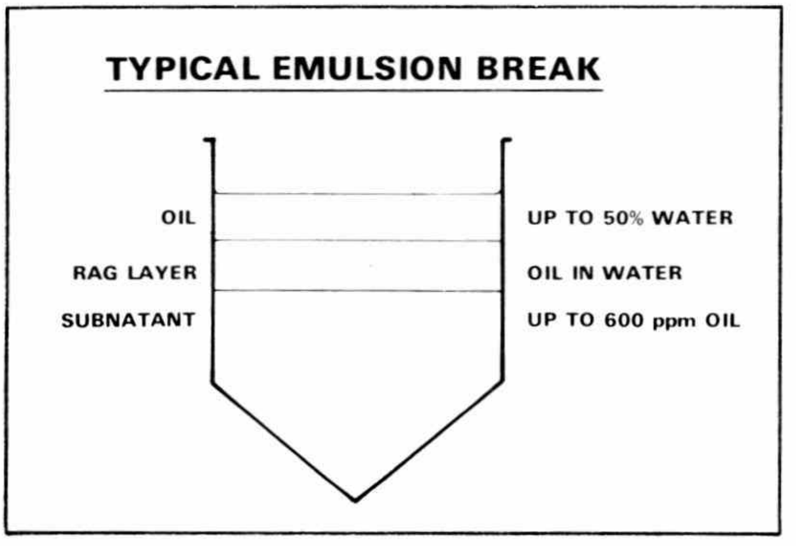
Section 1. Oil Emulsion Treatment

Spent oil emulsions are periodically dumped from any one of eight cold rolling mills. The emulsions contain up to 4% oil. There is also a continuous flow of oil emulsion from some of these mills. Miscellaneous oil sumps from the roll grinders, pickle lines and galvanizing lines are also tied into the collection system.



The emulsions are pumped from holding tanks at the mills to two heated collection tanks. These tanks are 40,000 and 60,000 US gallons capacity and are located in a storage building remote from the treatment plant.

The emulsions are preheated to 190°F and then pumped to one of two 15,000 US gallon agitated reaction vessels. These vessels are constructed of mild steel, lined with carpenter 20 alloy. Concentrated (98%) sulphuric acid is added to the contents of the reaction vessel to lower the pH of the solution to 1. The agitator is run for about 30 minutes to thoroughly mix the contents allowing the sulphuric acid to break the bond between the oil and the emulsifier. The contents are then allowed to settle.



The broken emulsion normally contains three layers. The top layer contains up to 50% water in oil. The second rag layer is an oil/water emulsion. This is left in the reaction vessel for further treatment. The subnatant contains up to 600 ppm oil, depending upon the type of emulsion being broken. This averages 250 ppm when the emulsion breaks easily. The oil layer containing up to 50% water is skimmed into a 1000 US gallon holding tank. Caustic soda solution is carefully added to neutralize the acid that is trapped in the oil. If excess caustic soda is added, soaps will form. The soaps are very viscous and difficult to pump. Some water settles out in the skimmings holding tank and is pumped to the neutralization tank for further treatment (see Section 2).

The oil still containing 40 to 50% water is pumped to a 15,000 US gallon heated settling tank where the temperature is maintained at 190°F.

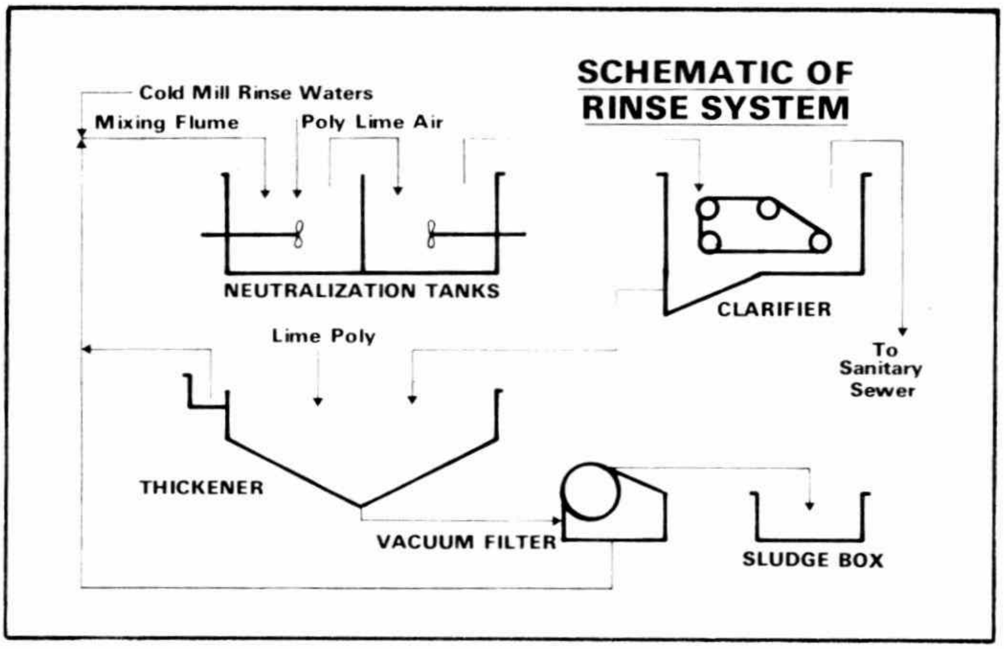
We have never produced oil of sufficient quality to burn as a bunker fuel substitute. Several improvements are being implemented to upgrade the oil quality. These will be discussed in detail later in the paper.

The oil containing 40 to 50% water is skimmed from the settling tank to a 4000 US gallon heated holding tank and then transported by truck to the coal piles where it is sprayed on the coal to suppress dust.

The acidic underflow from the reaction vessel is pumped to a neutralization tank or to a secondary holding tank. The treatment of this effluent will be explained in Section 2.

Section 2. Acidic and Alkaline Solution Treatment.

Several operations produce both continuous rinse flows and batch dumps of acidic and alkaline wastes. The dilute rinses are pumped directly to the treatment plant. The concentrated acidic and alkaline solutions are stored in holding tanks and slowly bled into the rinse system. This prevents sudden surges in influent concentration.



The various influents mix in a flume and then flow to the first of two 7500 US gallon agitated, aerated neutralization tanks. The underflow from the oil emulsion system and wastes from the ion exchange are also treated in the neutralization tank. The ion exchange wastes are bled from the same secondary holding tank that is used for the subnatant from the emulsion treatment system. Lime is added to control the pH between 7.5 and 9.5. Polyelectrolyte is added to aid flocculation. The tank is aerated to separate oil from the particulate and to oxidize ferrous hydroxide to the better settling ferric hydroxide. The waste flows into a second agitated, aerated vessel and then into one of two clarifiers. The clarifiers are 14' wide by 66' long and 18' deep. Floating oil and scum are removed from the surface by mechanical skimmers. The skimmings

are pumped to the oil reaction tank. The clarifier overflows to the City of Hamilton sanitary sewer. The following table shows a typical effluent analysis.

EFFLUENT ANALYSIS

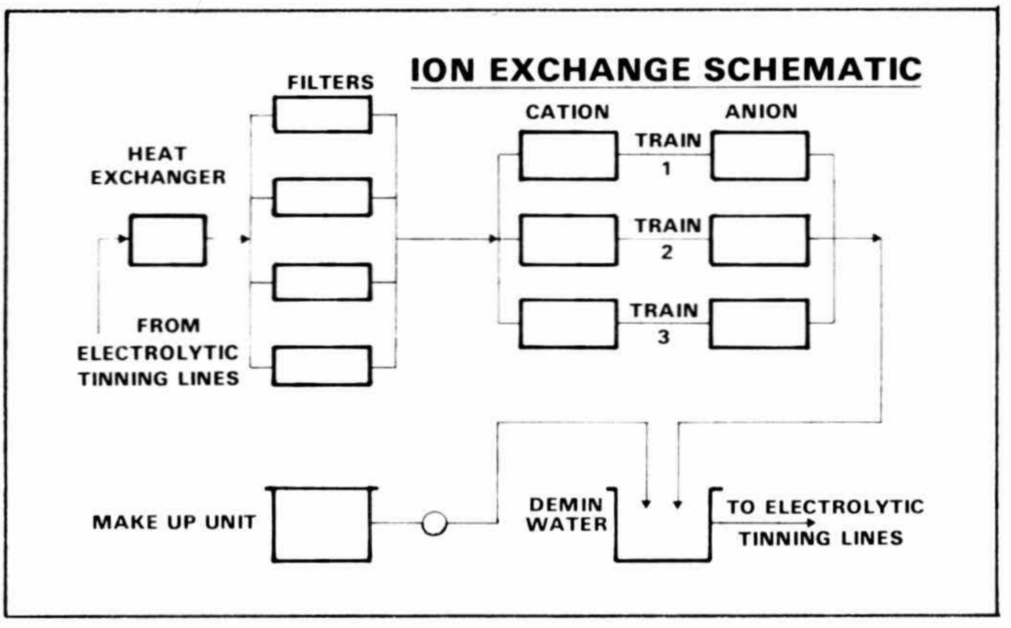
TEMPERATURE	100 – 130°F
OILS	10 – 50 mg/l
pH	7.5 – 9.5
SUSPENDED SOLIDS	200 – 300 mg/l
BIOCHEMICAL OXYGEN DEMAND	50 – 100 mg/l
CHROMIUM	LESS THAN 1 mg/l

The clarifier underflow contains up to 4% solids. This is pumped by moyno pumps to a 30' diameter thickener. Poly-electrolyte and lime are added to aid settling. The under-flow contains up to 15% solids. This is dewatered on one of two 8' diameter by 8' long rotary drum vacuum filters. The sludge is hauled away for landfill.

Section 3. Sodium Dichromate Solution Treatment

The final process, when producing electrolytic tin plate, is an electro-chemical treatment to prevent corrosion. The tin plate is passed through a bath of concentrated sodium dichromate solution. The excess sodium dichromate is rinsed from the strip using recycled, demineralized water.

The concentrated solution eventually becomes contaminated and is slowly bled into the rinse flow that is continously pumped to an ion exchange system at the cold mill waste treatment plant.



The total flow from two lines varies between 80 and 150 USGPM. The average chromium content is 94 mg/l (Cr^{6+}). The rinse water temperature is about 120°F The temperature is lowered to about 85°F by passing the solution through a heat exchanger. This extends the effective lifetime of the ion exchange resins. The solution is then filtered through any of four dual media filters. These filters contain sand and anthracite. The solution then flows through any two of three cation/anion exchanger trains in series. The first train on

stream is the primary train, the other being the secondary. The third train is being regenerated or is on standby. A complex network of valves and piping enables each cation/anion train to operate in the primary, secondary and regeneration modes.

Sodium Dichromate, in solution, produces sodium (positive) and dichromate (negative) ions. The cation exchanger removes sodium (Na^{+}) ions and substitutes hydrogen (H^{+}) ions. The anion unit exchanges hydroxyl (OH^{-}) for dichromate ($Cr_2O_7^{2-}$) ions. The resultant demineralized water is recycled to the chemical treatment rinse sections of both tinning lines. The following table compares the quality of the demineralized water with the water previously used as 'E' Line rinse water.

WATER QUALITY

	E–LINE WATER	DEMINERALIZED WATER
Cr	<0.2 ppm	N.D.
Ca	70 ppm	N.D.
Mg	8.5 ppm	N.D.
Zn	0.04 ppm	0.02 ppm
Fe	N.D.	N.D.
Cl^{1}	28 ppm	<0.2ppm
ALK, AS $CaCO_3$	64 ppm	0 ppm
TOTAL HARDNESS AS $CaCO_3$	124 ppm	0.2 ppm
SUSPENDED SOLIDS	5.5 ppm	3.0 ppm
pH	7.1	5.2
CONDUCTIVITY	300 μmhos	3 μmhos

The design data for the ion exchange units follows......

	Cation	Anion
Vessel diameter	8'-0"	7'-6"
Vessel height	11'-0"	11'-0"
Resin type	Lewatit * SP-112	Lewatit * MP-64
Resin Volume	280 cu. ft.	210 cu. ft.

* Lewatit is a Bayer Co. Trade Name.

More cation resin is used to enable both the cation and anion exchangers to exhaust at the same time. The primary train is considered exhausted when:

a) The chromium content in the solution entering the anion exchanger equals the chromium content in the solution leaving, or when,

b) The demineralized water conductivity rises to 100 μmhos.

When the primary train is exhausted, the secondary train becomes the primary train and the newly regenerated train becomes the secondary train.

Cation Regeneration

Initially the cation exchanger is backwashed with demineralized water. This water is recovered and recycled through the other ion exchanger trains. An 8% sulphuric acid solution is then pumped through the cation unit.

Hydrogen ions exchange with sodium ions and sodium sulphate is produced. This is collected in a storage tank and gradually bled into the neutralization tank (See Section 2).

The train is rinsed with demineralized water to remove excess sulphuric acid and then put on standby or used in the secondary train.

Anion Regeneration

The anion resin is backwashed with demineralized water which is recovered and recycled through the ion exchange system. Caustic soda solution is used to regenerate the anion resin. The caustic soda comes from two sources.

1) Caustic soda (3-5%^{w}/w) contaminated with sodium dichromate from the previous regeneration.

2) Caustic soda (7%^{w}/w) to replace the amount used in the regenerated sodium dichromate.

The regeneration is controlled by timers, tank levels, pH controllers and conductivity measurements.

As the caustic soda is added, starting with the caustic soda/sodium dichromate mixture, the following steps occur.....

a) Demineralized water is recovered until the pH of the solution leaving the anion exchanger reaches 5.8,

b) Sodium dichromate is recovered until the pH reaches 7.5 (At this point the caustic soda starts to break through). The dichromate is stored in a holding tank.

c) A mixture of sodium dichromate and caustic soda is recovered and stored for re-use in the next regeneration.

After a predetermined time the ion exchange unit is rinsed free of caustic soda. This is recovered in a holding tank and made up to strength (7%) with 40 to 50% caustic soda solution. The anion unit is then put on standby or used in the secondary train.

About 5% of the demineralized water is lost through ion exchange regenerations, filter backwashings, sampling and spills. This is made up by a 20 USGPM demineralizer.

Demineralized water has been recycled to the 'E' Lines since December of 1974. At present only a small percentage of regenerated sodium dichromate has been used because the sulphate content is too high.

The following table shows a typical regenerated sodium dichromate analysis and the analytical requirements for sodium dichromate in the chemical treatment of tin plate.

SODIUM DICHROMATE ANALYSES

	REGENERATED DICHROMATE	'E' LINE REQUIREMENT
$Na_2Cr_2O_7$	30 – 50 g/l	26 – 30 g/l
Sn	Trace	Trace
Fe	2.0 ppm	$<$2.0 ppm
SO_4	300 – 2000 ppm	$<$ 250 ppm
pH	6.8 – 7.5	4.5 – 6.0

The regenerated sodium dichromate is deep well buried.

COMMISSIONING PROBLEMS

As mentioned earlier this plant has had numerous start up problems. This section deals with some of the major ones.

PROCESS PROBLEMS

1) Oil Quality.

   The oil quality has been lower than expected because of the following:

   a) Reduced residence time in the settling vessels caused by higher than design throughputs.

   b) Extraneous water entering the collection points at the mills. This also increased throughputs.

   c) Various types of emulsions are mixed in the holding tanks. Individual emulsions were relatively easy to break but the mixed emulsions became much more difficult.

   d) Difficulty in accurately neutralizing the water trapped in the oil skimmings. Excess caustic soda reacts with the oil to form soaps.

We have been attempting to eliminate extraneous water sources at the mills. Experiments have been done using various chemicals to break the emulsions but sulphuric acid is the most economical. Water washing the oil skimmings to remove acid, instead of caustic neutralization, would require more space than is available. Testing showed that the solids content in the oil was as high as 1% by weight.

We are experimenting with a centrifuge to reduce both the solids and water content. The initial results indicate that oil can be produced containing less than 1% by weight of solids and water. The underflow requires further treatment to remove residual oil.

There is a potential market for good quality recovered oil and this will help offset the plant operating costs.

2) Oily Sludge Build-up.

This occurred in several places.

a) Oil Holding Tanks. We have experienced problems throughout the mill areas with sludge build-up at the bottom of the oil holding tanks. This material is hard to handle since it melts above 190°F. The oil binds to iron particles becoming denser than the oil emulsion. The tanks are pumped out, using submersible pumps and steam cleaned.

b) Clarifier. After six months operation we experienced a sludge build-up in the clarifier. Floating oil had reacted with caustic wastes and agglomerated with iron particles to form a dense soapy sludge. The clarifier rake mechanism was unable to handle this dense sludge. The water was pumped out using a submersible pump and the sludge manually removed.

Following this the operators were made more aware of the importance of oil skimming and the sludge outlet piping was enlarged to facilitate easier sludge removal.

c) Vacuum Filter. The thickener underflow contains oil and grease. This eventually blinds the vacuum filter cloth and support plates. The cloth and plates require cleaning every 3 to 4 months.

3) Thickener Operation.

Good thickener operation is the key to good vacuum filter operation. Initially the thickener was not operating correctly. The sludge in the underflow was too thin. The light sludge was being lifted by the rake mechanism. At times the overflow was above 500 ppm suspended solids. The underflow piping was also undersized. This piping was enlarged and the rake mechanism slowed from 1.5 to 1.0 rpm. Lime and polymer are also added to the thickener inlet to aid settling.

4) Ion Exchange Problems.

a) High Sulphate levels in the regenerated sodium dichromate. We are investigating methods of sulphate reduction. The sulphate level in the influent is being monitored. Reduction by precipitation using barium carbonate, preferential

ion exchange and reverse osmosis will be investigated.

b) Green sludge in Regenerated Sodium Dichromate. This sludge is chromium hydroxide (Cr $(OH)_2$). The presence of this sludge indicates that the resin is being oxidized by chromic acid (CrO_3). As the precipitate builds up on the resin, the volume of the demineralized water used to rinse the resin increases from a standard 15 to 20 times the bed volume to about 30 times bed volume. At this point the anion resin should be treated with 10% sulphuric acid for 16 to 18 hours and then rinsed with demineralized water.

MATERIALS OF CONSTRUCTION PROBLEMS

1) Fibreglass reinforced pipe.
We have experienced problems with fibreglass reinforced plastic pipe (FRP) when long lengths were needed to transport hot (180°F) liquids. The pipes expand and cannot take the stress, consequently the reinforced plastic cracks and leaks occur.
We propose to install polypropylene lined mild steel pipe.

2) Reaction Vessel.
The carpenter 20 lined, mild steel reaction vessel

has corroded due to a local reaction between water and sulphuric acid. This was repaired and both vessels are periodically inspected for evidence of further corrosion.

3) **Oil Skimmings Tank.**

The oil skimmings tank is a fibreglass-lined mild steel vessel. The lining cracked because of differences in the expansion of the two materials. The vessel was temporarily repaired and is being replaced with a solid fibreglass vessel.

MECHANICAL PROBLEMS

The main mechanical problem was the thickener rake mechanism. The torque on the rake mechanism increased because sludge built up in the thickener. This caused excessive wear on the drive mechanism. The drive mechanism was replaced and an automatic rake lifting device has been installed, which has successfully prevented further damage.

ECONOMICS

No discussion of effluent treatment would be complete without considering the economics involved. The treatment plant and collection network cost about $7 million. The plant is operated by 3 men per shift, 7 days a week. Four maintenance men work a 40 hour week in the plant. Additional service is supplied in some areas by local maintenance groups.

At present there is no credit for recovered oil or regenerated sodium dichromate. Primary treatment of cold mill waste water by this method currently costs about 90¢ per 1000 US gallons.

SUMMARY

This method of primary treatment of cold mill wastes has caused process, materials of construction and mechanical problems, but after more than two years of operation we are making progress towards resolving these problems.

The plant meets the effluent discharge specifications and tests indicate that a re-usable oil can be produced.

We feel that this method of cold mill waste treatment fills our requirements.

DESIGN AND OPERATION OF AN ACTIVATED CARBON WASTEWATER PRETREATMENT SYSTEM

Ken C. Bradley

INTRODUCTION

UNIROYAL CHEMICAL manufactures in Elmira, Ontario, a broad range of complex organics for use in the rubber and agricultural industries. Before 1976 all aqueous wastes from direct contact with these products, their intermediates, and raw materials, except the very high strength wastes, were treated in Elmira in this fashion. Following one or other of settling, skimming, chemically treating, recycling and/or neutralization, they were equalized at pH 7-8 in a large 30 day holding capacity aerated facultative lagoon system. The first two of the three lagoons that make up this system provided a reduction of about 1/3 to the strength of the wastes flowing through them. The effluent from this lagoon system was given a final fine neutralization, and in the winter months a steam treatment to raise the temperature to about 10°C, prior to discharge to a combined sewer to be mixed with the sanitary sewer flow from the town with all its other commercial and industrial sewage discharges.

This combined flow was then fed to the jointly financed UNIROYAL:Town activated sludge water pollution control plant (WPCP) for secondary treatment prior to ultimate disposal in the Canagagigue Creek. Now, the system includes carbon pretreatment between the second and third lagoons, just upstream of the final fine neutralization.

Although the WPCP was intended to receive and treat up to 1/3 more lb. BOD_5 per year from UNIROYAL than had ever deen delivered, it was soon recognized that it could not accept this quantity because a treatable waste was not being directed to it. In 1970-72 steps were taken by UNIROYAL to decrease its organic loading by about 67% on the assumption that a semi-starved activated sludge "bug" would have the incentive to learn how to degrade an inhibitory organic and perhaps even learn to like it. Unfortunately to some extent he chose to eat his neighbour. The WPCP final effluent BOD_5 did drop to the 17-25 mg/l. range from the much higher levels of previous years, but effluent quality was still substandard (Table I).

The Ministry of the Environment was aware of physical-chemical treatment studies we were conducting in conjunction with biological treatment work during late 1971 and 1972, and now imposed new WPCP effluent objectives that could only be met in Elmira by advanced treatment technology such as activated carbon. Many other studies employing solvent extraction, chemical oxidation, reverse osmosis, complete recycle, and even additional bio-oxidation, were undertaken before we concluded that some form of carbon adsorption would provide our best answer to this problem. After adsorption work with fly-ash and powdered carbon in stirred reactors, column studies showed that granular carbon either in a pretreatment step on UNIROYAL wastes or as a tertiary treatment step on the wpcp final effluent could provide the practical means by which an acceptable discharge to the Canagagigue Creek would result. Both our laboratory and pilot pretreatment work suggested, as shown in Table 2, that the new effluent requirements could be met (pro-

vided no drastic changes took place in the Town sewage which is downstream from our carbon treatment system.

DESIGN CRITERIA

We interpreted laboratory isotherm and column data showing both incomplete adsorption and a broad wavefront to indicate either a very large series column arrangement, or preferably, a single counter-current pulsed bed system. Other laboratory column studies involving both up and down-flow systems provided us with the data we needed to select the appropriate pilot system.

A single counter-current pulsed bed system was chosen for a number of reasons:

1. It would enable discharge of only the most completely spent carbon without requiring excessively large adsorption equipment and high carbon inventories.

2. It would minimize plugging from suspended solids and biological growth. To eliminate this problem entirely, an expanded pulsed bed system was chosen.

3. Less piping, valves, tankage, and carbon transport systems would be required. This would minimize capital, operating, and maintenance costs.

4. Laboratory column studies with four glass 1" O.D. columns (fig.1) showed the up-flow expanded bed system to be equally impressive at removing non-biodegradable or inhibitory organics as a similar down-flow system.

The pilot system consisted of 5-1/2" O.D. plexiglas pipe sections glued together into a 19 ft. high column. This is illustrated in Fig. 2. A stainless steel cone fitted with inlet pipe, and a plastic"water softener" distributor was used to keep the waste feed inlet open. Air operated ball valves at the top and bottom were connected via solenoids to electrical timers.

This unit ran continuously pulsing in and out predetermined quantities of carbon automatically at preselected intervals, usually every two hours. A continuous sampler was put on the effluent to obtain hourly composites for analysis during the day. Data was gathered from operating this system for several months. We found that Calgon's F-300 carbon or equivalent of 8 to 30 mesh allowed a much wider range of satisfactory velocities than did carbon of 12 to 40 mesh. The minimum flow below which plugging and lifting of sections of the bed occurred was about 1.7 imp. gals./min./ft.^{2} with both particle ranges. The upper flow limits beyond which excessive bed expansion occurred appeared to be close to 5 igpm/ft.^{2} for the 8 to 30 mesh carbon and only 2 igpm/ft.^{2} for the 12 to 40 mesh carbon. Contrary to our laboratory-scale column operation, no prior suspended solids removal was effected before introducing the plant waste water to the adsorption column, and with the right range of flow rates no serious problems were encountered. Suspended solids in the feed were well over 100 mg/l. on occasion.

Biological activity within the column did not present any problems unless the flow rate was too low or was shut off for a few hours. Then the resulting growth knitted the carbon granules together and the entire bed would rise when the flow was turned back on.

Studies were conducted to confirm the laboratory column data of optimum COD applied per lb. of carbon, contact time required, and COD removal capability. Because COD removal is not necessarily exclusively related to degree of adsorption on carbon (see Fig. 3), loadings were calculated from changes in apparent densities. Removals were determined from analysis of influent and effluent, and chemical oxygen demand removed was compared with loading on the carbon.

COD/BOD ratios in the feed and column effluent were determined to note the change in biodegradability. In addition, the carbon-treated waste water was tested for its effect on the Elmira WPCP (Fig. 4). To do this, we operated three laboratory-scale continuous flow activated sludge units as follows:

Unit I	Elmira town sewage only
Unit II	Town sewage plus carbon-treated UNIROYAL wastes
Unit III	Town sewage plus UNIROYAL wastes (monitor of the full-scale Treatment plant)

These units were actually operated at higher flow rates appropriate to some future expectations for the WPCP. A condensed summary of results is shown in Table 2B.

C. E. Raymond/Bartlett Snow performed carbon reactivation tests on three drums of our spent carbon in their 12-1/2 ft. long pilot rotary kiln. This provided us with reactivated carbon to compare with virgin material on the basis of adsorptive capacity to our own unique waste water COD constituents. It also provided us with data to size our reactivation furnace.

Carbon treatment pilot data is described in greater detail in other papers[1].

START-UP AND OPERATING PROBLEMS

After design collaboration with A. X. Hiltgen of Zurn Industries Inc., we purchased the services of Zurn's Enviro-Systems Division to provide pre-engineering, drawings and equipment specifications. UNIROYAL CHEMICAL's Engineering Department acted as project co-ordinator for construction and installation. The plant Waste Control Co-ordinator looked after start-up and operator training. Treatment began in the early spring of 1976. Figures 5 and 6 show the adsorber and "S" shaped spent carbon discharge pipe respectively. The wet side started well with very few problems and only a few equipment modifications were made. The furnace and off-gas scrubbing system start-up was much more time consuming. An oversized burner in the furnace probably contributed to most of our early problems.

Initial operating problems consisted of frequent power failurs which required rotation of the kiln by hand to prevent potential sagging of the

shell and burning of thermowells which caused the automatic temperature controllers to go haywire. More recent problems have been associated with the salt content of our wastewater and failures in the off-gas scrubbing system. Evaporation of water in the kiln allows build-ups of salt to plug the exit and to cause thermowell breakage. Occasional pre-cooler and scrubber nozzle replacement is required because of the acid off-gases, probably resulting from removal of organic chlorine and sulfur compounds from the spent carbon. Fig. 7 shows pre-cooler piping and nozzles of 316 SS after about a couple of months service. Fig. 8 is a photograph of the remains of test coupons after a few months in the wet end of the kiln where the atmosphere is believed to be the most corrosive. No coupon survived completely unscathed. Apparently the selection of 316 stainless steel for the lifting flights was about as good a choice as any. Problems with the scrubber itself consist of greasy carbon and salt sludge plugging the fan blade clearance and exhaust vent and separation of the protective resin coatings from the steel shell and other parts. This tends to cause scrubber fan inefficiency resulting in smoke and fume discharge into the building. The fan itself seems to be undersized.

Shortly after kiln problems became more manageable, problems with the wet side surfaced. A 316 stainless steel eductor is used for moving reactivated quenched carbon in slurry form back up to the top of the adsorber. Wear in the eductor throat soon caused increasingly higher pump pressure requirements to move the carbon. This probably increased the rate of wear. Carbonates started to plate out on the inside of the carbon slurry piping restricting the flow of carbon from the furnace back to the adsorber. Attrition of the carbon from slag at the joints in the welded stainless steel piping appears to be the cause of carbon bed depth measuring problems. The smaller granules seem to result in excessive bed fluidization, making it difficult to determine the carbon-water interface. In October the adsorber developed its first leak. This resulted from carbon erosion of the lining at the bottom exit of the mild steel cone followed by corrosion through the weld at the junction of the stainless discharge pipe.

We hope eductor wear can be lessened with changes in materials of construction. We are also considering replacement of welded slurry pipe with flanged pipe ground smooth inside the flanges, and with larger radius sweeping curves at the bends. This should reduce carbon attrition. Reduction of attrition will also reduce our carbon loss. The replacement in January of the phenolic epoxy-lined mild steel adsorber with a stainless steel structure should eliminate leaks. Lowering the pH of the lagoon system closer to 7 seems to have eliminated carbonate deposition in the slurry piping system.

Major continuing problems with the furnace system seem to be plugging of the exit caused by inorganic salts in the water on the spent carbon, failure of thermowells, and plugging of the scrubber from wet salts, and carbon fines. Recently the brake-lining seal at the firing end wore out and the main kiln rotation bearing failed. Problems are to be expected when equipment is subjected to a new application. We still believe we made the correct furnace choice for our system. Also, it is to the manufacturer's credit that he is concerned enough to listen to our problems and try to help.

COSTS

Capital cost of the complete system was \$450,000. This included the following major items:

- waste water feed pumps (one standby)
- microstrainer
- adsorber feed pumps (one standby)
- expanded pulsed bed adsorber
- clarifier
- carbon make-up tank with pump, eductor and piping
- sump pumps (one standby)
- control and annunciator panels with remote alarm for automated operation
- one rotary kiln with wet carbon feed hopper, dewatering screw, afterburner and off-gas scrubber
- one quench tank with pump, eductor and piping
- foundations, concrete block building and system installation

Our Waste Control Co-ordinator is supervising system operation and maintenance with assistance from our Engineering Department.

What we feel is unique about this installation is its simplicity. Fig. 9 shows the flowschematic. There is no spent carbon storage tank. Spent carbon flows by gravity directly to the furnace feed hopper. This eliminates the need for one complete handling of carbon. There is also no reactivated carbon storage tank. Reactivated carbon is quenched and fed directly to the top of the adsorber where it falls back into service. This eliminates the need for one more complete carbon handling system. No backwashing or air-scouring equipment is required. This also reduces carbon attrition. Biological growth can occur in the adsorber all it likes with no operating problems. This capability is provided by the counter-current expanded pulsed bed.

Operating costs have been approximately 20¢/lb. of chemical oxygen demand treated.

Three big items account for most of the operating costs at this stage: repairs and maintenance, operating labour and make-up carbon. We are still modifying the system by experimentation, and we are still running into unexpected breakdowns. Both these causes of high maintenance expenditures should be reduced in frequency as time progresses. We expect this to eventually allow operating labour to be cut from eight hours per shift to just a couple of hours per shift. When there are no problems, the system does run by itself. Operating labour should then consist of checking controls, temperatures, flow-rates, etc., every few hours, and adding make-up carbon every day or two.

Several attempts at measuring make-up requirements seemed to show carbon losses in the range of 4-1/2 to 6-1/2 percent. At about 58¢/lb., this can be a significant expense. By reducing attrition and improving our housekeeping, we hope to cut our losses to 4% or less. By accepting spent carbon from others, we should reduce our costs further, and at the same time help others reduce theirs.

Normal operating costs won't really be known until we achieve a standard operation. This could easily take a year or more.

TREATMENT EFFICIENCY AND MONITORING

As our waste water characteristics change, so does the efficiency of removal of organics by activated carbon. In general, chemical oxygen demand (COD) is lowered by over 50%, BOD_5 by about 15%, colour by 95%, and phenolic equivalent by over 99%. This occurs by contacting for about one hour no more than about 0.7 lbs. of COD per lb. of carbon. The organic loading on the carbon is then about 20%, which is apparently close to the maximum for good reactivation[2, 3 and 4]. Measurement of the loss in adsorptive capacity after successive reactivations so far has only been attempted on two or three occasions. Adsorption isotherms were performed comparing COD adsorption from our wastewater by reactivated carbon and by retained samples of virgin carbon. See Figure 10. The differences observed from this test so far do not appear significant.

Table 2B, as previously noted, shows laboratory data comparing secondary treatment of wastewaters as they were in 1973 vs. secondary treatment of material after pilot carbon treatment of UNIROYAL process wastes.

Table 3 contains actual plant data using BOD_5 and phenolic equivalent values reported by the Ministry of the Environment's laboratories on Highway 401. The COD values are our own because we believe the chloride correction necessary for our wastes is not used in the Ministry's analyses.

Data over a longer period of time would have been available by now except for start-up and operating problems which are taking so long to iron out. Unfortunately, our lagoons up-stream of our carbon treatment system have not recently had sufficient operating capacity to enable us to store all our process waste waters during all periods of carbon system repair. If downtime is much over a week, some by-passing of process waste waters must be activated or two of our lagoons would overflow.

System monitoring is generally by three times per week analysis of carbon and water samples taken every shift into daily composites. Carbon adsorption and reactivation is determined by measurement of apparent density. This is a simple test which shows the weight picked up in the adsorption cycle and lost again by reactivation. We relate this to changes in adsorptive capacity by performing occasional laboratory chemical oxygen demand (COD), or total organic carbon (TOC) adsorption isotherms.

On the spot monitoring of treatment performance is done by visual inspection of an effluent sample (Figure 11) and also by checking the sample for odour. COD or TOC, and colour removals are checked three times each week by our Waste Control laboratory. The final lagoon effluent after equalization with cooling tower blowdown is monitored the same way, and in addition, phenolic equivalent is determined. Because this material is directed to the joint UNIROYAL: Town Water Pollution Control Plant (WPCP), samples are taken once a week for analysis of a dozen different parameters by the Ministry of the Environment. The Ministry performs the same tests on samples of the Town sewage, samples throughout the WPCP and samples of the final effluent. In addition, we analyze for colour and fish toxicity.

Occasional biodegradability tests are also performed by our Waste Con-

trol Laboratory because carbon has been shown in our pilot testing to improve the CODtoBOD ratio from about 3 to 1 to about 1.4 to 1. For comparison, that of the town sewage feed has been measured at about 1.8 to 1.

CONCLUSION

Design, construction and installation of our carbon pretreatment system was a major process waste treatment project involving relatively new technology. Operation of the system is still a major project.

To this somewhat unproven technology we introduced significant design changes which stemmed from our early collaborative efforts with Zurn. Because of its unique and simplified design, I think we can say that this installation represents an advance in the application of this technology, and I feel that UNIROYAL's management deserves a lot of credit for the very positive way in which we were encouraged to do this. We were encouraged to see what systems were available, to modify them if appropriate, or to design our own. Then, the faith that Management placed in its technical people when this involved not only new technology but new technology beset with problems, was a very gratifying experience.

With all other things held fairly constant, we are very confident that as our experience grows and operating problems become better managed, the Elmira WPCP will consistently generate an effluent BOD_5 of 10 mg/l. or better, phenolic equivalent will be well below 20 ppb, and effluent quality in general will be much improved.

REFERENCES

1. K. C. Bradley, "Design of an Activated Carbon Waste Water Treatment System for a Multi-Product Organic Chemical Plant,"

   Proceedings of the Fourth Annual Industrial Pollution Conference of WWEMA, March 30 - April 1, 1976, Houston, Texas.

2. T. B. Henshaw, "Activated Carbon System Reduces Toxic Phenols from Herbicide Plant Effluent", Filtration Engineering, July/August, 1972.

3. J. T. Truemper, "Granular Activated Carbons", from a symposium presented by ICI America, Inc., Library of Congress Cat. Card No. 67-31379, page 77.

4. Water Treatment by Adsorption, I. Optimal regeneration conditions for activated carbon used for the treatment of dye manufacturing waste water, C.A. Vol. 83, No. 6, Aug. 11, 1975, 47873r.

Table 1

1972 WPCP FE Quality

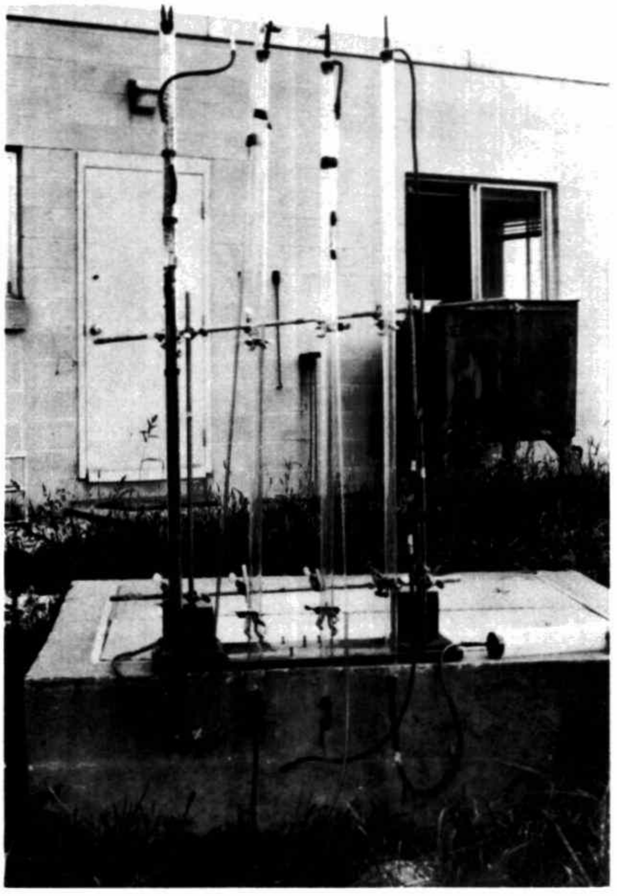
BOD_5	17 ppm
Suspended Solids	51 ppm
Phenolic equivalent	188 ppb
Colour (APHA)	165 units
Appearance	Cloudy

Table 2

Activated Sludge Treatment Studies

Parameter	WPCP	Laboratory Feed to WPCP	Units Treating: Town Sewage	TS+CTU*	Objective
A. April, May & June 1972 Laboratory Carbon Columns					
Influent BOD (ppm)	-	100	40	55	N.A.
Effluent BOD (ppm)	-	12	17	9	10 Max.
Effluent COD (ppm)	-	145	42	75	100 Max.
Effluent Phenolic equiv.(ppb)	-	151	29	27	20 max.
B. March, April, & May 1973 Pilot Carbon Column					
Influent BOD (ppm)	173	268	149	242	N.A.
Effluent BOD (ppm)	28	17	10	7	10 Max.
Effluent COD (ppm)	168	189	32	80	100 Max.
Effluent Phenolic equiv. (ppb)	171	373	8	9	20 Max.
Effluent Colour (APHA)	191	198	12	14	25 Max.

*TS + CTU = Town Sewage plus carbon treated UNIROYAL Wastes.



(Fig. 1) Laboratory Carbon Column Up-flow Set-up

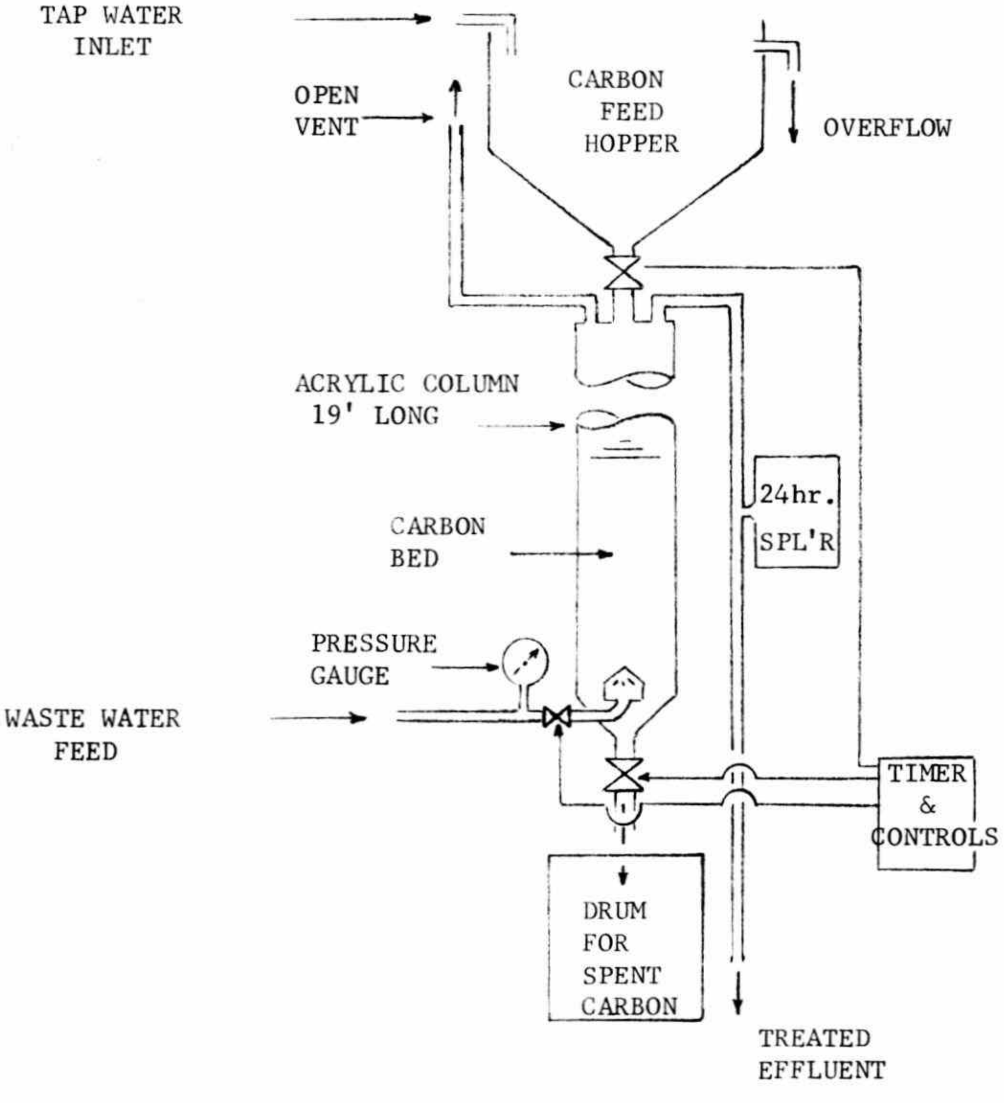


Fig. 2 PULSED BED CARBON ADSORPTION COLUMN

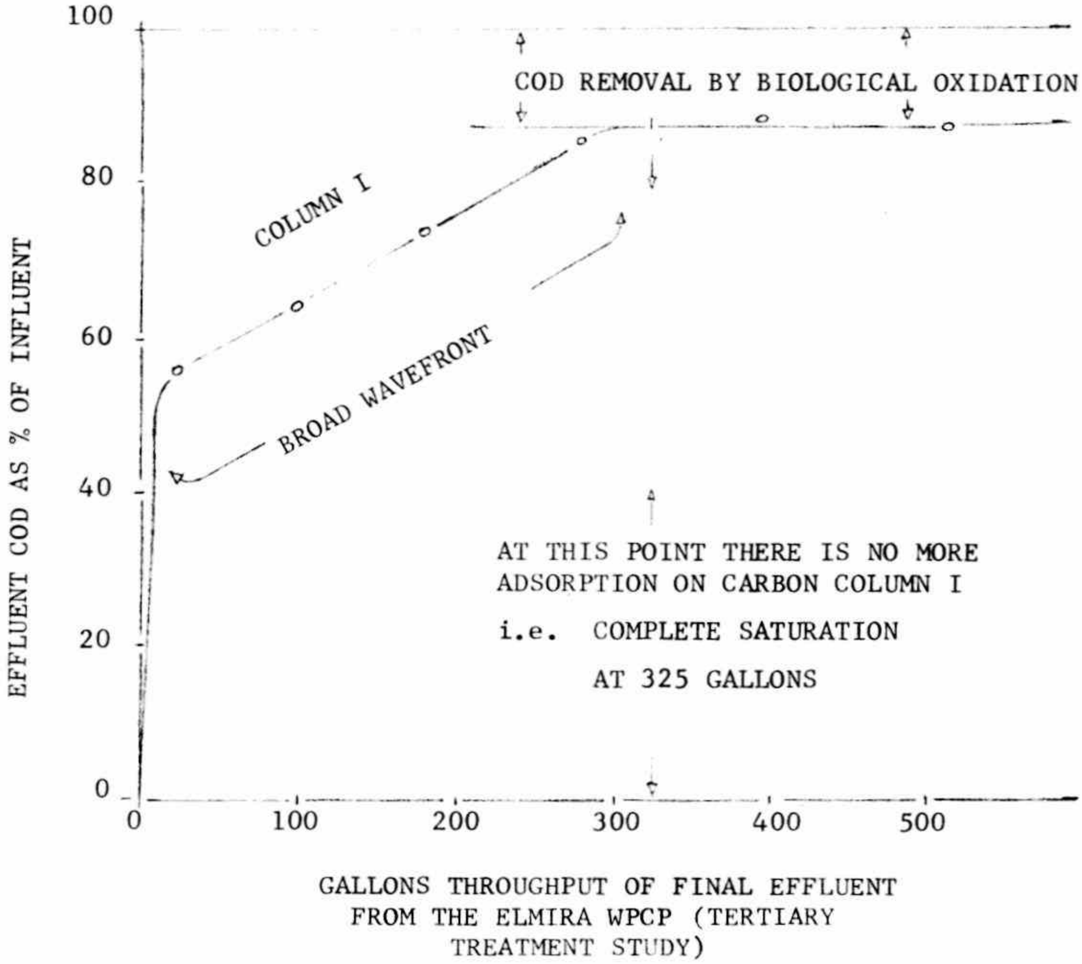


Fig.3 <u>Determination of Throughput For Initial Saturation</u>

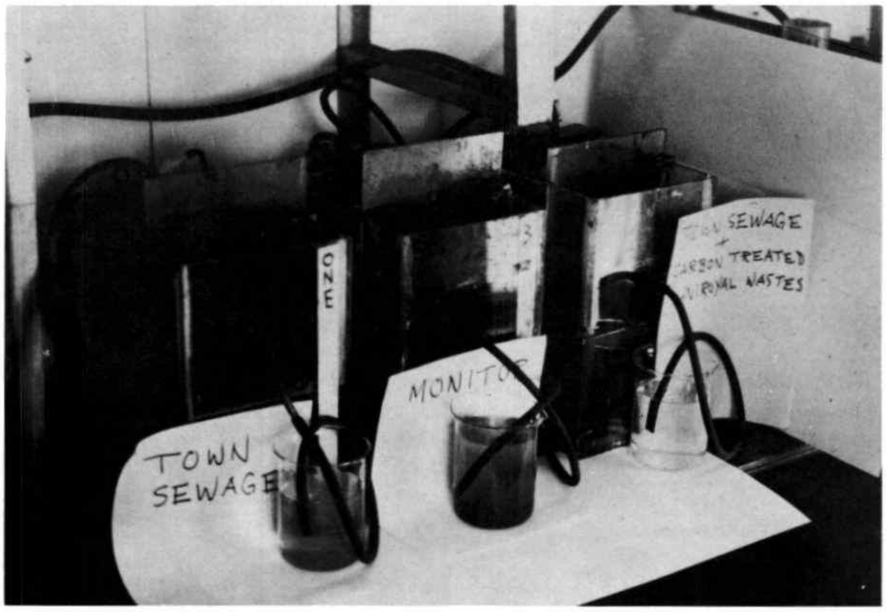


Fig. 4 Laboratory-Scale Continuous Flow Activated Sludge Units (The one on the right is receiving sewage plus carbon treated UNIROYAL wastes.)

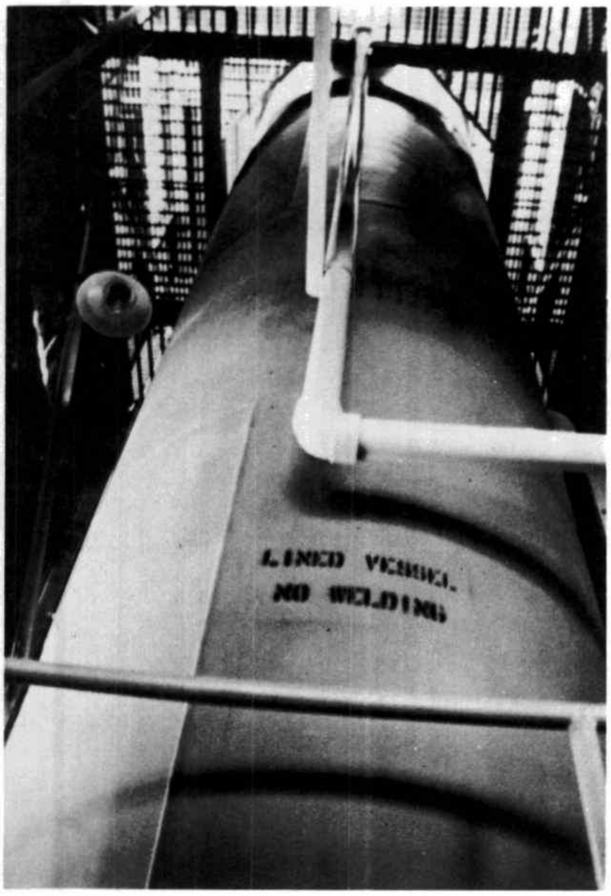


Fig. 5 Carbon Adsorber

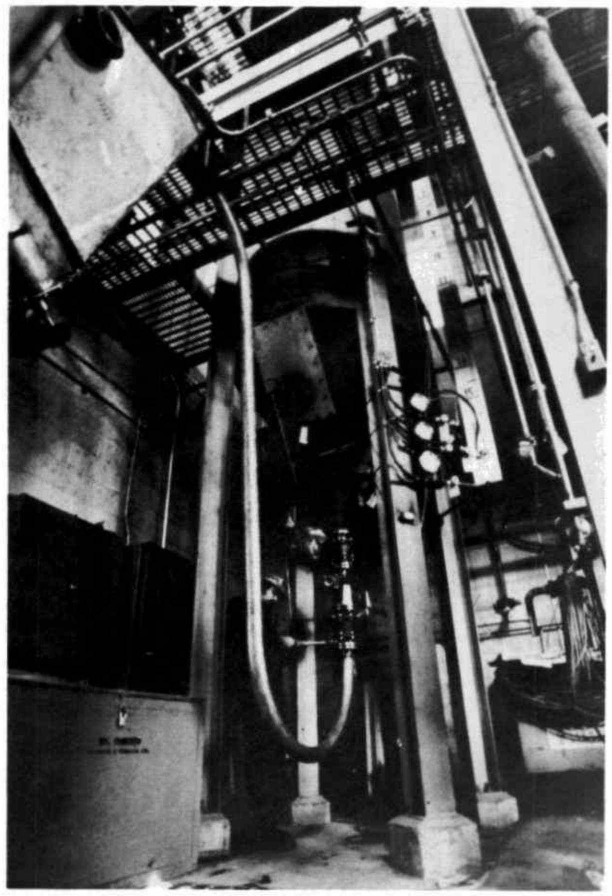


Fig. 6 Spent Carbon Discharge Pipe from Bottom of Adsorber

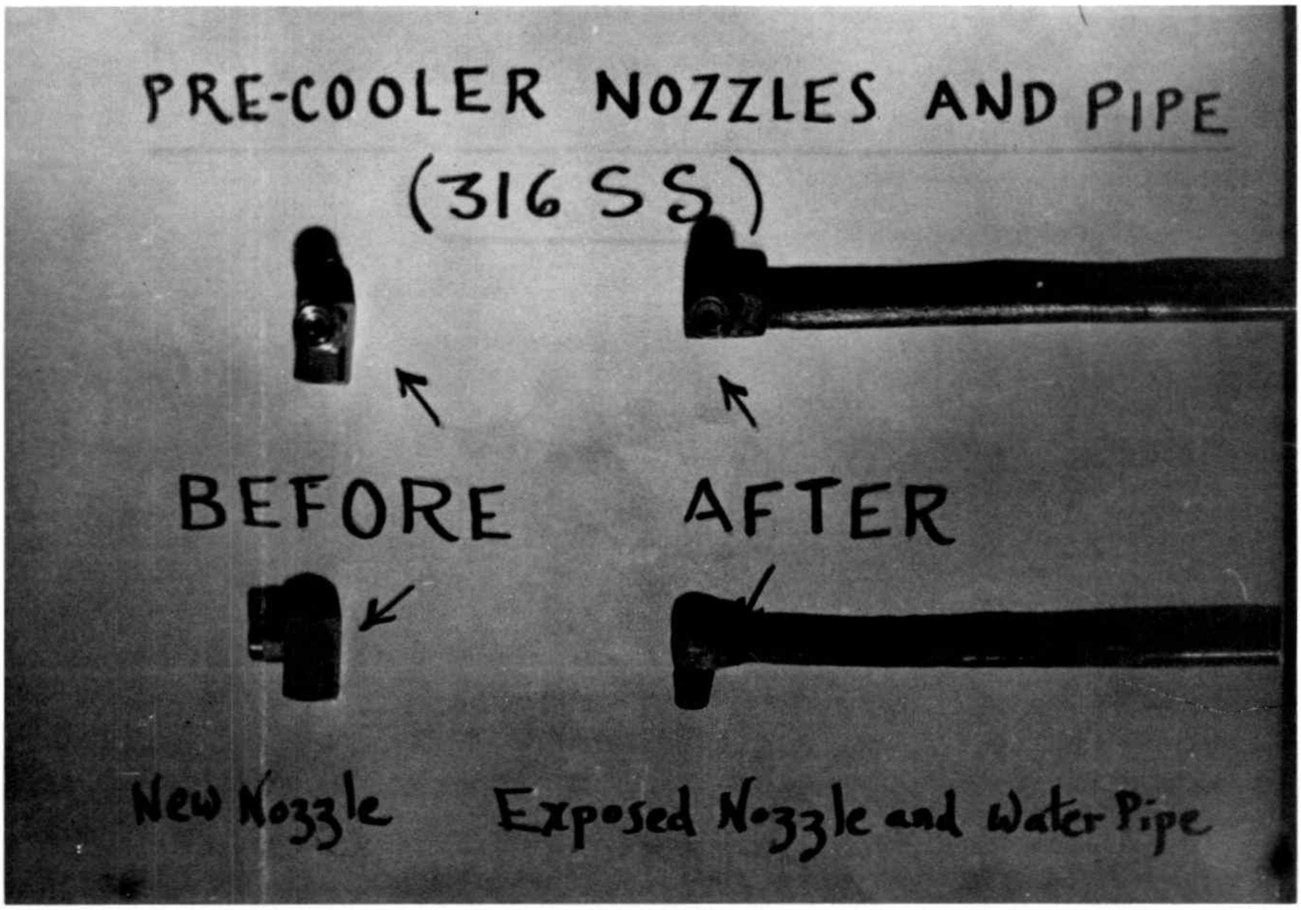


Fig. 7 Spray Nozzles after Two Months Service Cooling Acidic Furnace Off-Gases

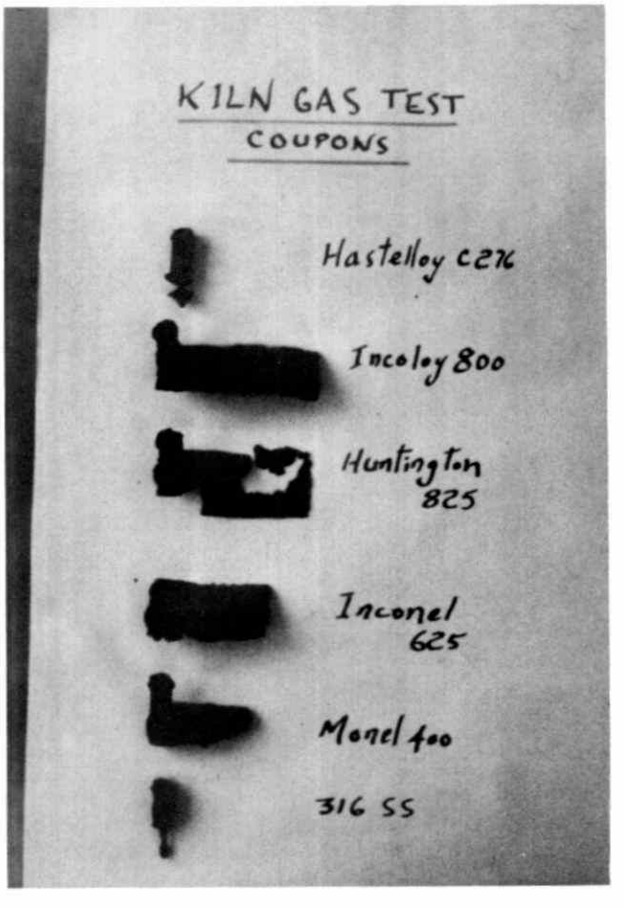


Fig. 8 Coupons from Inside Wet End of Furnace

Fig. 9 CARBON TREATMENT SYSTEM

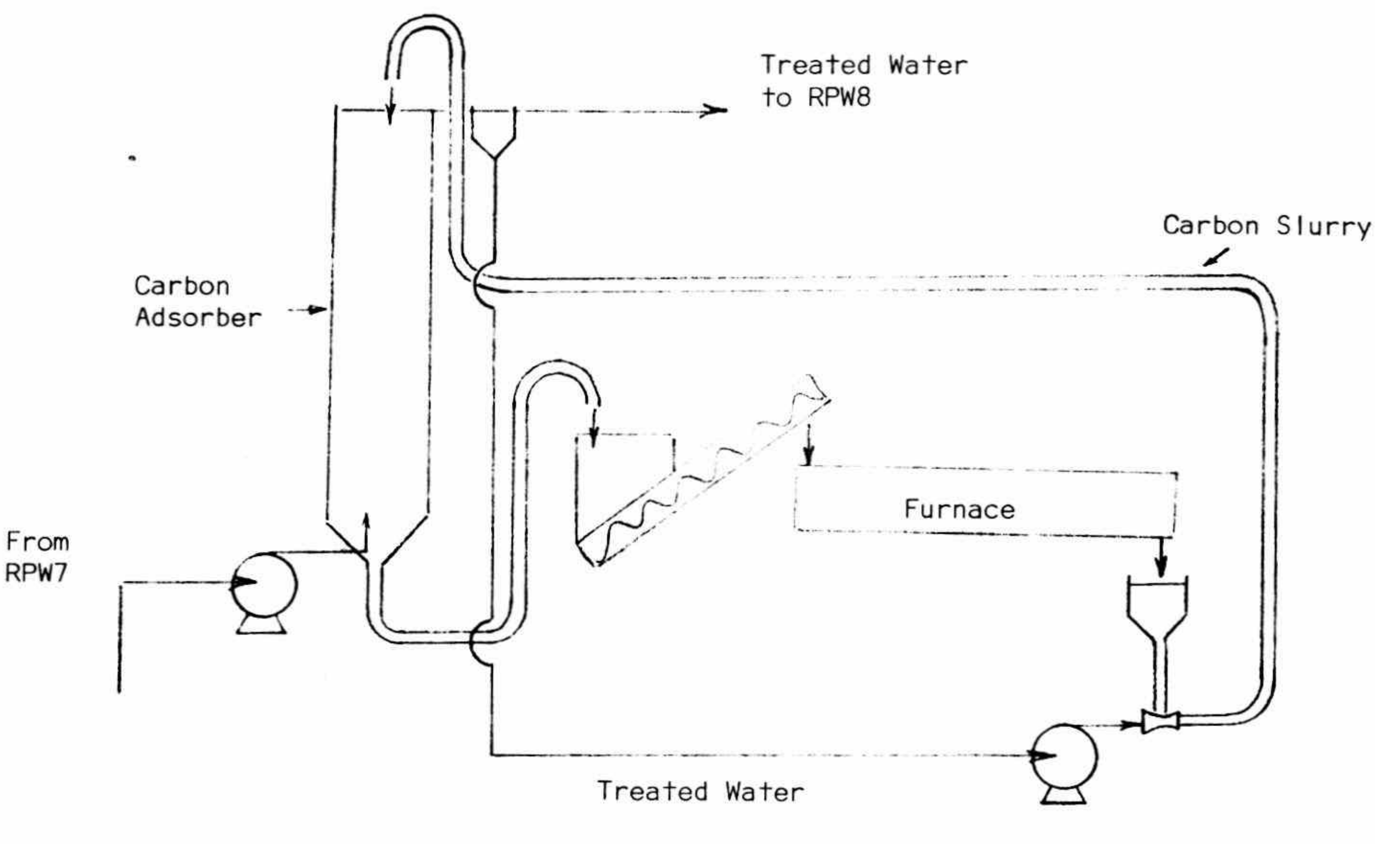


Fig. 10 COD Adsorption Isotherms on Waste Water Feed to Bldg. 44

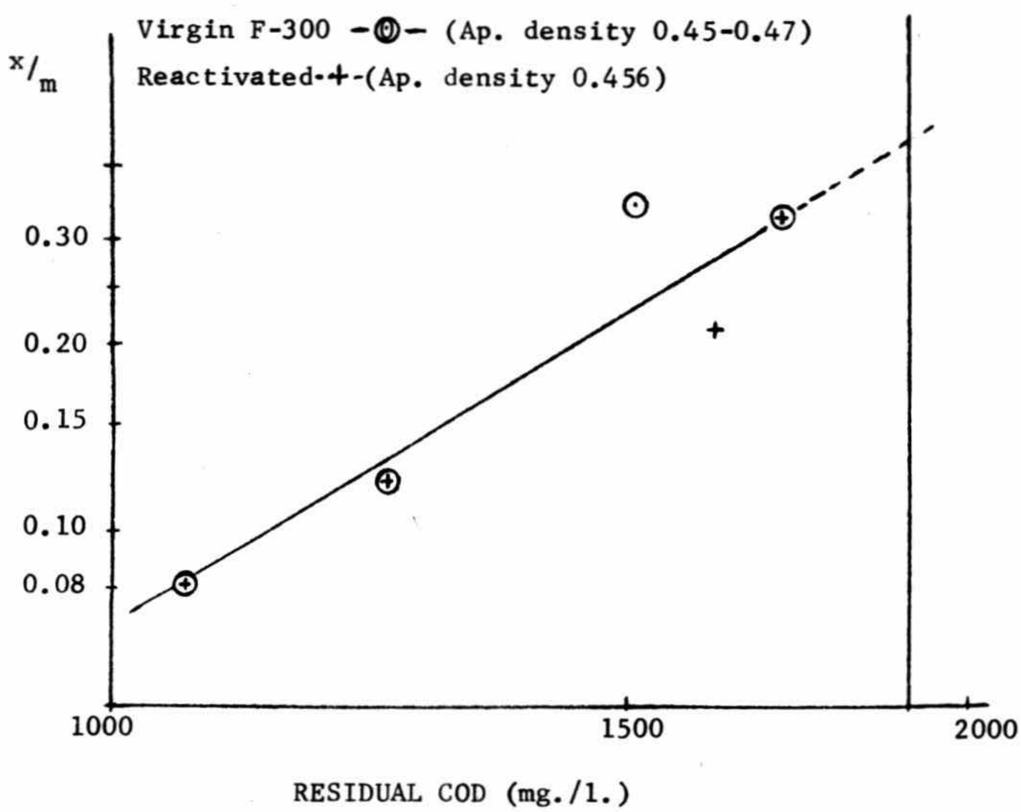


TABLE 3

WPCP EFFLUENT RESULTS

July, August, September & October
(Averaged)

PARAMETER	LAB	1975 BEFORE CARBON	1976 AFTER CARBON	LIMIT
BOD_5 (ppm)	M. of E.	14.5	8.6	10
COD (ppm)	Uniroyal	163	78.5	100
Phenolic eq. (ppb)	M. of E.	36	8.9	20
MBAS as LAS	M. of E.	1.2	0.4	-

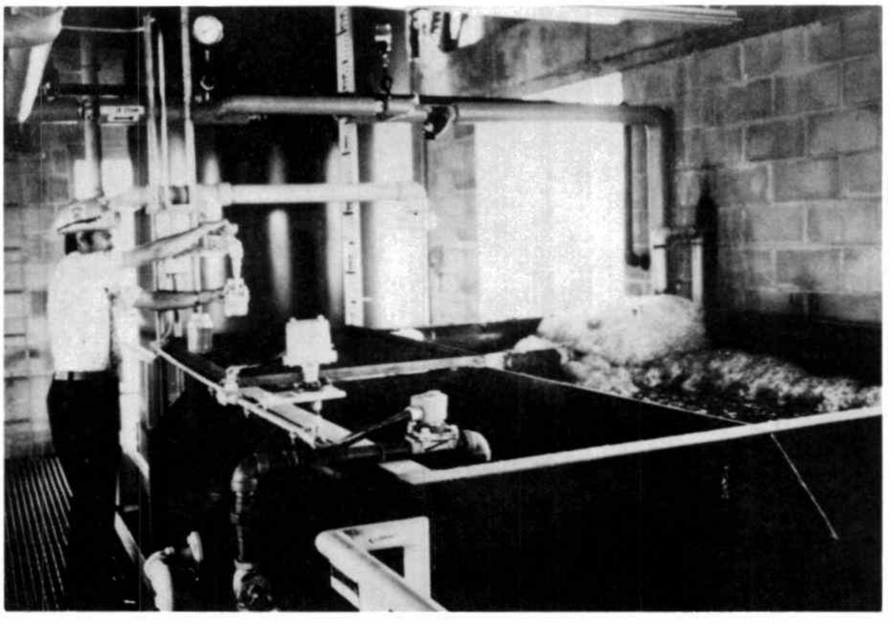


Fig. 11 Sample of Carbon Treated Wastes
(Compare with influent sample at the left)

DEVELOPMENT, START-UP AND OPERATION OF A BIO-OXIDATION TREATMENT FACILITY FOR A HIGH SALINE WASTE STREAM

E. A. Sommers

The Sarnia complex of Dow Chemical of Canada, Limited is located on the banks of the St. Clair River which is, as you probably all know, a major waterway separating Ontario and Michigan. Although the river is primarily of importance to deep sea shipping, there are many areas of it that enjoy recreational uses, fishing being one of the most heavily subscribed to. Up until relatively recent years, there has been a tendency by municipalities and industry alike to use convenient bodies of water as disposal sites for waste materials, generally believing in the powers of dilution; this use of natural resources has been and still is being continued to varying degrees around the world and the St. Clair River is no exception. The past few years, however, have slowly seen steady improvement in both attitutde and technical capability with the result that there has been, at least, a halt to the process of water quality regression.

Since the nineteen sixties, Dow has been producing increasing amounts of propylene oxide in Sarnia, but it was not until 1971 that increased concern with regards to salt loadings in fresh water suggested that some action be taken. Owing to the chemistry involved in the method of producing the oxide, a copious waste water stream of 6% brine is being wasted at present. Initially, the immediate answer to the problem was to recycle this waste stream to the Chlor-Alkali plant where the weak brine could be made use of. However, data from previous experience pointed out that the presence of trace organics, normally found in this waste stream, would

cause major intolerable process problems in chlorine production. With the removal of the organic contaminants becoming of such paramount importance, an investigation was rapidly initiated into determining the path to be followed to allow a successful recycle of this waste stream from the Glycol Plant steam strippers.

Initial studies were wholly based on previously published facts and figures and the information so gathered was applied to the character and volume of the stream in question. Among the several methods tentatively examined were:

(1) Direct chlorination or hypochlorination

(2) Ozone oxidation

(3) Carbon adsorption

(4) Biological treatment

As these initial studies were completed prior to my joining the project, I can comment only sparingly on the various findings that were compiled. Apparently, owing to several awkward problem areas, carbon adsorption was abandoned at a very early stage in the investigation. The three other areas were examined more closely as to their comparative costs of treating steam stripper effluent containing up to 500ppm of total organic carbon. Total capital costs for various TOC levels showed that as the TOC concentration increased from 100ppm to 500ppm, a spread became obvious with the costs for chlorination increasing more rapidly than those for Ozone oxidation, the costs for which, in turn, increased much faster than those for biological treatment. The same comparisons were made for annual operating costs and much the same results were recorded. At the time that these studies were being made, TOC concentrations from the steam strippers were running fairly steadily in the region of 400ppm. After all the available data had been compiled and closely examined, there was very little doubt but that the only feasible path to adopt was the one leading to biological oxidation.

Initially, it had been proposed that viable biological treatment would not be possible at salt concentrations much above 2%, with no possibility existing of diluting the 5%-10% feed stream down to this level; this condition would have stopped the project immediately. However, for several months prior to the cost studies, work had been progressing under an EPA contract at the Dow complex in Freeport, Texas; the theme of this work was "A Study on the Removal of Various Organics from a Saline Waste Stream." Results of this mini-plant study implied that it should be quite feasible to construct and run a full scale process. It was considered to be too great a jump to go from mini-scale to plant scale, so it was decided to construct a pilot scale unit capable of handling a maximum flow of 150GPM; due to available space, it was also decided to erect this unit at the Freeport site. The components of the pilot unit were fairly basic as regards bio-treatment and included a large equalization pond to smooth out any wide fluctuations in temperature, organic concentration and alkalinity. The aeration basin was a plastic lined pond having a capacity of 40000 gallons and equipped with a 50HP surface aerator located at the centre and guyed with four wires to hold it in position. Aeration pond mixed liquor flowed by gravity to clarifier tank from which settled solids could be pumped back to the aeration pond or forward to a sludge thickener. Overflow from the clarifier could flow, also by gravity, to a flocculator tank for treatment with ferric or aluminum and caustic. The final overflow from th flocculator was allowed to flow to the site sewer system while the flocculated solids were transferred to the thickener. At start-up, the microbial mass in the aeration basin was propagated from a seed obtained from the mini-plant. The original seed as cultivated in the mini-plant had its inception in the sludges and slimes of the ditches and ponds in the Texas Division where glycol waste-water commonly flowed. At this stage, the required culture was grown in glass tanks by

a slow process of acclimation over a six week period. The starting medium was a solution of 300-400ppm propylene glycol in 3% brine and this was gradually increased over the period to 10% brine. The culture was progressively concentrated by the normal fill-and-draw technique and the concentrate was freeze dried for future use. In the Pilot Plant, the freeze-dried bacteria were brought back to life in the aeration basin and were acclimated to onstream conditions by a batch process. Due mainly to equipment problems, there was a four month period of adjustment before a really successful start-up could actually be initiated, at which time, the serious task of collecting data was commenced. During a two year period, until late 1973, various testing programs were tried out; these ranged from "efficiency of oxidation of the organics" through "flocculation and sludge thickening," salt-washing of sludge," "sludge stabilization" and "sludge de-watering." Each of these programs was exhaustively examined so that a maximum of good solid data could be collected and applied to the final design of a full scale operating plant. During the investigation into de-watering, various methods were examined, but only two methods were physically tested in the plant; these were centrifuging and pressure filtering. With a continuous centrifuge, the solids were increased from a maximum of 2% in the sludge feed to about 25% in the final waste material. Using a multi-plate pressure filter, the corresponding numbers increased from 2% to around the 40% mark. Although there was a marked difference in initial costs between the two pieces of equipment, with the pressure filter being substantially higher than the centrifuge, it was decided that the lower expected maintenance costs coupled with the more easily handled filter cake would ultimately offset any other disadvantage. By mid-1973, sufficient data had been logged with respect to equipment performance and operating parameters to allow a start to be made on the actual design of a full-scale facility for the Sarnia location. The final expectations as to the quality of treated effluent based on a compilation of Pilot Plant

readings were: Propylene Glycol reduced by 90% and TOC reduced by 80%. No really meaningful data was collected on the average expected clarity of the effluent.

In Sarnia, the design phase and the ordering and collection of equipment lasted until mid 1974, at which time the proposed site was cleared and ready for construction. The period of heavy construction lasted about one year with a few of the minor piping and electrical jobs going on in to the late fall of 1975. In October of that year, we were in a position to water test most of the equipment for possible leaks and in November we were, in effect, ready for business. Basically, the only major difference between the Pilot Plant and the full scale unit is the comparative size of the individual components; the line function is the same: the raw steam stripper discharge enters an equalizing tank before travelling through the aeration basin, clarifier and flocculator and finally into a holding pond or to the sewer. Examining the system in greater detail, the raw waste stream enters the Bio-Ox battery limits at a temperature of 160 degrees fahrenheit and at a pH of 11-11.5. At this stage, primary neutralization is carried out, reducing the pH to about 10.7 with a controlled addition of 35% hydrochloric acid; optimum mixing is achieved by an in-line Kenics mixer which is simply an extension of the pipeline containing a series of rotated static helices which causes a repeated splitting of the liquid stream. Although the pH reduction at this point appears very minimal, it does, in fact, remove a substantial amount of free caustic. The equalization tank is a vessel 40 feet high and 125 feet in diameter and was originally equipped with a large side-mounted mixer to prevent channeling between inlet and outlet. After a short spell in service, and several toxic incidents, it was decided to dispense with this method of mixing and instal a diffuser pipe; this consisted of extending the raw feed line to the centre of the equalization tank and drilling diffuser holes along the length of the extension in such a manner that the incoming flow would be directed upward at a 180 degrees from the tank discharge point.

Operations since this step was taken have proved its efficiency. Under steady running conditions, a tank level of 60% is maintained to allow a suitable mixing volume while, at the same time, ensuring reserve capacity for production surges at the propylene oxide facility. Temperature reduction from 160 degrees at this stage is minimal and an external source of cooling has to be employed to lower the waste stream to the operating level of 80-90 degrees fahrenheit; this is accomplished in an exchanger using river water as coolant on the shell side. Final pH adjustment and the addition of nutrients are performed just prior to temperature reduction. Although Pilot Plant data had suggested a final pH of 9 in the feed going to the aeration basin, actual plant operations during 1976 had indicated a smoother process by supplying the basin with material at pH 10.5; there is, of course, the added benefit of money saved. The necessary nutrients, nitrogen and phosphorus, are added in the form of anhydrous ammonia and 75% phosphoric acid from on-site storage tanks. Initially, the nutrients were metered into the feed stream in amounts dependent on the total organic carbon (TOC) being fed to the basin and based on the theoretical ratio of TOC:N:P = 100:10:1. Day to day and even more frequently, fluctuations in TOC loading made this such an awkward procedure that it was dispensed with after a couple of months. Now, the amounts of nutrients added are dictated by the levels of ammonium ion and phosphate remaining in the overflow from the aeration basin; a conscious effort is made at trying to maintain the concentrations of these materials at some level less than 1ppm. It has been interesting to note that, operating in this fashion, results for the past year have generated a working ratio of TOC:N:P = 100:11:3. Analytical procedures employed in the determination of the nutrient excess are very standard: the ammonia is reacted with phenol and hypochlorite to produce the indophenol blue complex which is measured colorimetrically; the phosphate is reacted with molybdate and amino-naphthol-sulfonic acid to produce the molybdenum blue complex which is

similarly measured. Prior to analyses, care is taken to ensure the removal of all solids from the samples by filtration.

The steam stripper waste, adjusted for pH, temperature and nutrients , is now ready to be worked on by the bacteria. The aeration basin, home of the bacteria, is a large reinforced concrete structure measuring 130 feet in length and 65 feet wide; there are two operating depths available, at 15 feet and at 20 feet, and each of these is governed by a series of three 12 inch overflow ports. Feed to the basin is flow controlled and enters through three 8 inch ports. The oxygen necessary to sustain biological activity is supplied by a pair of Spenser air turbines each capable of supplying 6000 standard cubic feet per minute of air drawn from the atmosphere and discharged at a pressure of 10 psig. The air is supplied to a 16 inch header and this in turn supplies 24 rows of Kenics mixers; there are 11 mixers in each of these rows and all 264 mixers rest on the floor of the basin. Such a configuration gives a perfect mixing pattern for this particular vessel geometry and leaves no dead areas where solids can build up and form pockets of anaerobic material. For the initial start-up, which took place in October 1975, the aeration basin was isolated from the rest of the system and the required strains of bacteria were generated in a batch-type operation. On the basis of Pilot Plant findings, it had originally been suggested that seeding with freeze dried material from this facility would be the most expedient method of generating a colony; be this as it might, it was felt that access to a more readily available seed was a necessity for purposes of reactivation after a kill. Consequently, with the knowledge that the solids generated in a fresh water plant contain a full spectrum of species, about 12000 gallons of anaerobic sludge from the digesters of the Sarnia Sewage Treatment Plant were introduced into the aeration basin which had previously been charged with treated waste. Analyses were performed on the basin liquor to determine TOC, solids content, dissolved oxygen and propylene glycol content. Using these results as a

base, the same analyses were performed routinely several times every day to track the growth of viable strains and also afford valuable practice in laboratory techniques to the operating staff. Over a period of two weeks, the aerated mass showed a gradual color change, going from the initial slate grey color to a light brown; during the course of this change, there was an accelerated diminishing in the organic content. The bio-solids, after recording a dramatic reduction in concentration during the first few days, started to show a slow but steady growth. Before a zero concentration of propylene glycol was reached, the inlet and outlet lines to the basin were opened and at this point in time, the Bio-Oxidation Plant was considered to be truly in operation. Throughout this period of bacterial acclimation, dissolved oxygen (DO) was determined using an oxygen probe, but problems with the equipment and also in the translation of results persuaded a return to the more reliable Winkler method which, incidentally, is still the method presently in use.

With the placing of the aeration basin on line, it was a simple matter for the clarifier and flocculator to become operational; the overlow from the basin automatically flowed by gravity into the clarifier which was allowed to fill to the 50% level before the recycle sludge pumps were started and settled bio-mass was returned to the aeration basin. The clarifier is a circular concrete basin 100 feet in diameter with a side-water depth of 12 feet; it is equipped with a rotating rake mechanism which directs solids on the floor of the basin to a centre well and from there to the recycle pumps suction. Lighter, fluffier solids are picked up by a series of 6 inch diameter plastic lines mounted along the length of the raker arms and extending up to the liquid surface; these lines discharge into a sludge box and from there to the recycle pumps suction. There is a period of rotation of 30 minutes on the rake mechanism which is fast enough to collect the solids but yet is slow enough not to cause turbulence in the solids layer. The

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line carrying the recycle solids runs back to the head of the aeration basin and discharges at a point just below the surface. With a rapidly increasing bio-mass, a sidestream can be split off from the main recycle flow and wasted from the plant so that a steady level of solids can be maintained in the basin. Periodically, there can be varying amounts of solids floating on the surface of the clarifier and these are removed by the action of a skimmer bar attached to the raker arm. The flocculator has a function similar to that of the clarifier but has the added capability in that ferric chloride and caustic can be added to the influent stream and sufficient agitation supplied to maximize the scavenging action of the ferric hydroxide so formed; during the start-up period, this function was not made use of and the flocculator was simply used on a flow through basis, with the perimeter overflow being directed to the plant sewer and then to the St. Clair River. It should perhaps be mentioned at this time that several of the basins in the plant are equipped with domes which lend a somewhat futuristic appearance to the area; these domes are of spun styrofoam *Registered Trademark-Dow Chemical Co. covered with four layers of latex cement. Their function was primarily threefold:

(1) to reduce the spreading of possible odours

(2) to offset the hazard of mist forming on nearby highways due to steam generation

(3) to add to the overall appearance of the unit

The plant remained on start-up status for several months; i.e.: Waste Stream - Equalization Tank - Aeration Basin - Clarifier - Flocculator - Sewer plus, of course, Solids Recycle. During this period, there were several instances of bio-mass kills of varying degree; the partial kill was by far the most awkward to diagnose as there would still be sighn of biological activity. As a result it was possible to spend several days examining each operation parameter closely but never being able to regain complete oxidation. Unlike the fresh water system with

its myriad of species, the high saline system is known to contain only 6 or 7; for those who have an interest in bacteriology, the most numerous is reputed to be, quote: a gram negative, non-motile, lactose negative, oxidase positive rod, unquote. At any rate, the destruction of one or two of the component species exerts a marked effect on the efficiency of the colony and the only way to recover the efficiency is to resupply the system with its missing members; this was done on several occasions by simply adding 5000 or 6000 gallons of digester sludge to the aeration basin and, at the same time, cutting feed rates. These periodic jolts in the normally smooth running oxidation were traced to toxic effects due to surges in the concentrations of chlorinated hydrocarbons normally present at low levels in the waste feed. Knowing now the effects of these surges and knowing what the surges are caused by have led to much better communications between individual units within the Sarnia complex and this, in itself, is always a big plus in any large organization. Not nearly so drastic in effect, but still very troublesome, were periods of sudden high propylene glycol content. These caused shock effects of varying intensity often requiring up to a week of close controlling to correct. Throughout the entire initial six months of operation, there was an ongoing problem with floating, bulky layers of black anaerobic material in the clarifier; every conceivable change was made in recycle rates, loading levels, and hydraulic rentention times in the basin but every time there appeared to be an improvement, it was short-lived. Nevertheless, with a build-up of waste solids fast becoming a problem, it was decided to bring the salt-wash section on line. The salt-wash system owed its existence to the concern that these solids, which would normally contain a large percentage of 8% brine, might cause ground-water contamination. In recognition of this concern, it was decided to include a section in the plant that would be wholly devoted to removal of salt from the solids prior to land-fill. In Pilot Plant studies, it was investigated to see if the brine retained by filtered solids could

be washed out in situ, but experiments in this area were unsuccessful. Consequently, it was checked to see how efficiently the brine could be removed from the solids before filtration; results from this series of tests were so much more optimistic that final plant design included a series of four washer basins to be constructed. These four basins, also domed, are simply small-scale versions of the clarifier and, as such, included a raker mechanism to direct solids to a central draw-off sump. Each basin has a diameter of 35 feet and a side-water depth of 8 feet. In the plant, these basins are numbered S-3, S-4, S-5 and S-6 and during operations, the solids wasted from the process enter S-6 while fresh wash-water is supplied to S-3. By a series of overflows and underflows, the solids are worked back through the series of basins until they settle out in S-3 while the wash-water progresses through to S-6, becoming saltier as it goes, this salty wash-water is eventually pumped back into the main body of the plant where it becomes part of the effluent. The washed sludge is allowed to collect in S-3 until it is withdrawn for filtration. Mathematical formulae do exist to allow calculations to be made as to the reduction in salt content; these depend on the ratio of wash-water to sludge and the number of stages available but, in the plant, we have opted to go with actual results rather than worry as to whether or not theoretical guidelines are being followed. Suffice it to say, with a 4:1 water to sludge ratio, the salt content of the final filterable sludge can be reduced to about 0.1% from a starting level of 6-8%.

As has previously been mentioned, centrifugal de-watering of sludge was exhaustively examined in the pilot operation and was discarded in favour of pressure filtration which, although a semi-batch operation, tended to realize a more manageable product with much less problem. The filter system installed in the Sarnia location was manufactured by the Passavant Corporation in Birmingham, Alabama. The filter press itself is composed of 37 plates each 5 feet in diameter and weighing half a ton; these plates are hung from a centre travel beam and are sandwiched between two heavy pressure pieces, one static and the

other movable. For filtration, the two pieces are brought together with a closing pressure of 4500 psig before conditioned sludge is pumped into the plate stack to a final pressure of 225 psig at which time dewatering is considered to be complete. Unloading is accomplished by withdrawing the movable pressure piece back from the plate stack and activating a plate shifter mechanism which effectively moves each plate individually and allows the solid cake to drop into a disposal bucket. The most important step in the entire filtration process is the first one, that of conditioning the solids; without the right consistency, the filter cake will either be too hard and thin due to over-conditioning or too soft and pulpy due to under-conditioning. To carry out conditioning, the bio-solids from the final salt-wash settler are pumped to a reaction tank where they are mixed with preset amount of 40% ferric chloride and a 10% slurry of hydrated lime in water. It should be recognized that this method of conditioning bio-solids for filtration is by no means the most efficient; it is generally known that sludge is continuously varying in character and therefore the quantities of conditioning chemicals also have to vary. By trial and error, we at the Sarnia plant have simply arrived at an acceptable average; sometimes the bio-mass is overdosed, sometimes underdosed, but in the majority of instances, a good filter cake is produced. To remove most of the guesswork from solids conditioning, an R meter can be used; this measures the resistance to flow of the conditioned slurry using time as the measurable variable. After conditioning, the slurry is collected in holding tanks until such time as there is sufficient for a filter run. The filter medium used is a monofilament polypropylene cloth and as such, is reputedly prone to solids blinding. To prevent this problem occurring, it has always been the accepted procedure to precoat the cloth with diatomaceous earth or some such similar material; indeed, certain types of furnace flyash have been used most successfully in this capacity; extra insurance against blinding can also be obtained by body feeding, that is, by using extra

earth or flyash within the conditioned slurry. Precoating was discontinued at the Sarnia facility after it was inadventently discovered that an uncoated cloth remained cleaner and promoted better cake disengagement; the plant has been operating in this manner since mid-1976. Each filter cycle is capable of processing 60000 lbs. of conditioned sludge having a mixed solids content of 3% and producing 5000 lbs. of de-water cake. Although land-filling is the vehicle by which the final solids are disposed of here in Sarnia, incineration can be very easily employed by those with that capability.

It took from October 1975 until August 1976 to have all the various components of the Bio-Oxidation Plant in relatively smooth mechanical operation and since then, the emphasis has been on improving the quality of treatment, and especially the final effluent. As has been already mentioned, the ultimate aim of the treatment facility is to reduce chloride discharges to the St. Clair River and to do this, an effluent free enough from organics and solids to be usable by our Chlor-Alkali Plant must be produced. By far the most major problem to date has been the level of suspended solids in this final effluent brine. During all of 1976, concentrations of solids in the flocculator overflow have generally averaged about 150ppm. Various programmes of flocculation using ferric chloride and caustic were carried out and some of these resulted in very good removal of bio-solids; unfortunately, residues of iron were left which would cause even greater problems to a Chlor-Alkali plant. In further efforts to reconcile the solids problem, a poly-electrolyte addition system was fabricated and several weeks of tests were performed with and without iron addition; improvements, if any, were so minimal that this approach was finally abandoned. During one of the many reviews of recorded data, however, it was noted that there were indications of higher solids being present during periods of anaerobic formation in the clarifier. These periods had, in themselves, been a puzzle as they had never been accompanied with low oxygen readings; these were

invariably in the region of 1.5-2.5ppm. It was finally hypothesized that, due to their facultative character, the bacteria were periodically switching to anaerobic behavior despite the presence of oxygen. Tests performed with varying air rates and closely monitored oxygen readings finally led us to realize that dissolved oxygen concentrations were not the all important parameters they had been assumed to be; a quantity relationship between solids in the aeration basin and oxygen being supplied is much more meaningful. Operating on this premise, a marked improvement has been noticeable since January 1977; suspended solids in the final effluent have dropped from the high levels of 150ppm to a fairly steady level of 15-30ppm. As a direct result of this work flocculation investigations have been discontinued and the flocculator is now simply being used as a secondary clarifier. A further unexpected benefit was derived from these tests in that for weeks at a time, no solids wastage had been required to maintain steady bio-mass levels in the aeration basin; the colony appeared to be self-regulating as long as optimum air was being supplied. Any trending down of the air to mass ratio appeared to result in bio-mass growth requiring a waste stream to be drawn off.

The final component of the plant to be brought on line was a one million gallon capacity holding pond for final effluent. This was brought into service during February 1977, at which time the overflow from the flocculator was redirected from the sewer. After 4 or 5 weeks in service, there appeared to be a noticeable degrading of the pond contents; large areas of floating black sludge appeared then disappeared only to reappear larger than before. As time passed, the appearance of the pond degenerated rapidly to a point that called for some action. Temporary piping was installed to allow the pond contents to be recycled back through the salt-wash system and the accumulated solids filtered and disposed of. Prior to pumping out the pond, tentative explanations for the entire problem suggested a biological attack on the pond lining which was an asphalt and gravel affair. When the pond

level was low enough for a proper examination to be made, several samples of the asphalt were taken from areas which had been both above and below the liquid level; results indicated that all acetone soluble material had been stripped from the asphalt that had been submerged leaving behind a thin, brittle brown shell. It would appear that before the pond can be reinstated, some alternative to the asphalt will have to be found.

In summary then, the Sarnia Division Biological Oxidation Plant has been in operation now for a little over one year. The oxidation function is capable of running with a propylene glycol removal level of 90-100% based on feed rates of up to 900GPM and initial glycol concentrations averaging 350ppm. TOC removals of 80% appear to be the normal expectation; this particular figure tends to be misleading as it is felt that the TOC remaining in the effluent is due to lysis and in no way is representative of the original TOC; to avoid confusion, however, effluent TOC will continue to be calculated as a percentage of influent TOC. Efficiency of operation of the aeration basin is measured on the basis of the amount of propylene glycol remaining in the overflow, as the glycol contributes 99+% to the total organics present in the raw feed stream; the first appearance of a glycol peak on the chromatogram denotes an off-spec condition necessitating corrective action. The quality of the effluent brine has improved to the point of being tentatively acceptable for recycle testing; a testing programme, once it gets going, is scheduled to last at least six months before final evaluation. There has been and continues to be no problems attached to washing salt from waste sludge and the filtration system is equally trouble-free. On the basis of the past eighteen months of operational experience, I hope that in the not too distant future I can return with a sequel to this report detailing all the good things arising from a total wastewater recycle system.

SESSION IV

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Ontario Government's Hazardous Substances Program
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Geotechnical Aspects of Disposal and Containment of Low Level Radioactive Wastes
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ONTARIO GOVERNMENT'S HAZARDOUS SUBSTANCES PROGRAM

T.W. Cross

The total number of industrial chemicals to which the general population of Ontario may be exposed is enormous. According to a recent compilation prepared for the Ministry there are at least 3000 chemicals which are widely used by Canadian industry in significant quantities. There is evidence that many of these chemical substances may be hazardous to human health when encountered via occupational or environmental exposure . In addition to their inherent toxicity, some chemical compounds may decompose or react with other substances in the environment to produce products of high toxicity. This may occur even if the original compounds are relatively harmless. It is obvious therefore that a rational and systematic method must be employed to identify and assess potential problems in the environment which may arise from the use of these chemicals. The ultimate objective is to recommend or implement preventative or abatement action before a threat is posed to the community. Several agencies of the Government of Ontario have a legislative mandate to assess or regulate the effects of hazardous chemical substances on people, land, wildlife, vegetation, property, etc.

The Ministry of the Environment is currently carrying out and some other ministries are planning Province-wide inventories of toxic or hazardous chemicals to assist in assessing risk to various receptors. Many agencies of the Government make use of the results of research on the effects of a variety of chemicals and often carry out or sponsor such research themselves. These data bases and sources of information are essentially common to all of the programmes. Details of the applications and assessments of the data differ from agency to agency.

The specific activities of the agencies which are involved in one way or another with hazard assessments can be grouped into five major categories as follows:

- Development of qualitative and quantitative data bases on effects of chemicals in the biosphere;
- Identification and quantitation of chemicals which are present in the biosphere; and in the economy
- Assessment of hazard, risk, or stress created by exposure of living things or economic materials to the chemical products of human activity;
- Establishment of priorities among environmental, social, and economic stresses due to hazardous substances;
- Regulation and control of the levels of hazardous substances in the biosphere.

Three ministries of the Government of Ontario are particularly involved with the above activities, namely Environment, Labour, and Natural Resources. Their legislative mandates include the Environmental Assessment Act, the Environmental Protection Act, the Ontario Water Resources Act, the Pesticides Act, the Industrial Safety Act, the Employees' Health and Safety Act, the Silicosis Act, the Occupational Health and Safety Act (pending) , the Construction Safety Act, the Mining Act, the Game and Fish Act, etc, which all deal with biological hazards.

In order to coordinate and oversee activities associated with the Hazardous Substances Programme and to avoid duplication, the Ministry of the Environment has formed an Hazardous

Substances Committee (HASC). The terms of reference of HASC are:

1. To provide an inter-ministerial forum for:

   a) the identification and assessment of potentially hazardous materials on the basis of information provided by the Ministry of Health, other health protection agencies; and other sources;

   b) the evaluation of reports or summaries on for example, process and control technology, sampling and analytical techniques, and sources and source strengths of hazardous materials, which have been prepared with the assistance and cooperation of various branches or agencies;

   c) the discussion and preparation of recommendations to Ministry of the Environment management for action on existing or potential problems.

2. To provide advice to environmental standards-setting committees on hazardous substances;

3. To coordinate and expedite the flow of scientific and technical information on hazardous substances.

This committee is composed primarily of Ministry of the Environment scientists and engineers but also has representation from the Ministry of Labour, Environmental Health Studies Services, providing the beginning of the inter-ministerial forum mentioned in the terms of reference.

The Ontario Hazardous Substances List:

It is important to state the working definition of the term "hazardous substance". For the purpose of this programme, we are concerned primarily with industrial discharges of specific chemical compounds. A hazardous substance is one which poses an identifiable threat to community health in the quantity in which it is emitted to the environment. Thus, although a substance may be highly toxic to humans, it is not hazardous unless there is an opportunity for exposure to a quantity which will produce an adverse effect.

Information gathered during this programme is to be used to assess effects on health of the general human population due to chemical substances discharged by manufacturing and processing industries. The harmful quantity of a pollutant may refer either to the local community surrounding the emitting plant or to a much larger receptor population depending on the nature of the chemical substance and the extent of transport. The range of influence of a source may extend well beyond the adjacent community for tens or even hundreds of kilometers depending upon the properties of the emitted substance, prevailing meteorological conditions, hydrological factors, and disposal practices.

In order to establish a preliminary short list of potentially hazardous substances, it was decided to use two criteria: severity of human health effects and the extent of usage and production. A rough ranking index was calculated as the ratio of the total amount of substance used or produced in Canada to the Ontario Occupational Health Guideline concentra-

tion (Threshold Limit Value or TLV) for inhalation of that substance. These amounts, of course, do not necessarily bear any specific relationship to the amounts used or produced in Ontario, but they provide the only reasonable estimates of usage available to us at this time.

After eliminating those substances which were unlikely to lead to significant human exposure or which for other scientific and technical reasons were considered unlikely to be significant long term environmental contaminants, a short list of about 100 entries, comprising individual chemicals or classes of chemicals, was selected. This list was published in June 1976 as the Ministry of the Environment Hazardous Substances List (HASL).

In response to a request from Environment Canada, a somewhat shorter version of HASL was selected as a priority list by a joint ad hoc committee of the Ontario Ministries of Environment, Health, Labour and Natural Resources. The latter list appeared in September 1976 and was a somewhat more refined selection than the Ministry of the Environment Hazardous Substances List.

Subsequently, Environment Canada developed the Ontario submission along with submissions from many other agencies and individuals into a List of Priority Chemical Substances under the Environmental Contaminants Act. This list of 27 entries was published in late March 1977.

Further refinement of these various lists was necessary, however, to make them relevant to specific potential hazards in Ontario. The Ontario Hazardous Substances Committee decided to produce a brief, flexible priority list of the substances which

the best available scientific and technical information indicated as the most serious potential hazards in this province.

It is important to emphasize that all environmental media were represented in the input to the selection of priority substances: water, air, soil, waste, etc.

The purpose of maintaining a list of the Ministry's current priority chemical substances is not only to assist the Ministry in developing policy and in anticipating research and development needs, but also to inform industries and the community of concerns which may be expressed in the future in terms of regulations or control programmes.

The Hazardous Substances Committee developed a checklist of criteria to be used in selecting priority chemicals. This checklist is reproduced in Figure 1. About 20 individuals associated with the Committee as well as the complete spectrum of environmental media participated in an exercise to produce a consensus priority list based on the hazard rating checklist. Respondents were asked to select and rate approximately 15 substances. 26 substances (or classes) were cited 3 or more times, indicating a strong consensus on the candidate substances.

The list of substances which ranked highest by this procedure was then reviewed and each substance or class was assigned to a relative priority category. These categories are shown in Table 1. Category A, the highest category, comprises those substances which require immediate attention, including those for which Ministry programmes are currently underway. The next category (Category B) comprises those substances considered to be important but which do not require immediate attention or for which Ministry programmes are essentially complete (in the sense of control or monitoring activities already in place).

A third group of cited substances <u>(Category C)</u> were judged to be of low priority regarding Ministry activities in the immediate future.

These lists should be viewed as examples of the classes of substances which, for a wide variety of reasons, cause concern for their present or future impact on human health or the environment. The lists will change as our knowledge about their health effects, ecological effects, and discharges to the environment increases. That is, individual compounds may enter or leave the lists from time to time. The compilation of priority substances will be a better resource for decision making if it is kept flexible. The list in Table 1 is believed to contain most chemical substances or categories of substances which may present environmental contamination problems in the future. The Hazardous Substances List, then, should be regarded as a preliminary guide to the industrial chemicals or families of industrial chemicals for which data from the industrial sector in Ontario will be required in the near future.

It is anticipated that each substance identified as high priority will be the subject of a comprehensive background study. Various aspects of a specific pollutant may need to be investigated. These may include:

1) Physical and chemical properties.
2) Potential sources of discharges.
3) Process and control technology for reducing discharges.
4) Available sampling methods and analytical techniques and detection limits; research and development needs in this area.
5) Nature, persistence, and fate of the pollutant in the environment.
6) Environmental impact taking into account health effects, population affected, phytotoxicological effects, and soiling, corrosion, and odor characteristics.

In particular, source testing programs or ambient monitoring programs may be recommended.

A Source Inventory Based on the Priority Substances List:

The two basic components of hazard or risk are inherent toxicity and opportunity for exposure. In order to assess community exposure, it is necessary to know the quantity of each toxic substance which is being discharged at an industrial site, or more importantly, in total by all of the industries in a geographic or populated area.

As the first step in screening potentially hazardous situations the Ministry of the Environment has decided to pursue, a complete Province-wide inventory of selected substances from the priority list. The inventory is already underway and will eventually comprise specific locations and quantities produced or processed for each priority substance or class of substances. Once the potential sources of significant discharges of toxic substances have been identified, on the basis of the inventory, estimates or measurements of actual discharges will be made. Eventually, the significant sources of discharges which may endanger human health or the environment will be identified by this procedure and abatement or control programmes will be instituted.

Inventory data on hazardous substances will be acquired by a variety of means. Initially, it is likely that a combination of questionnaires and personal visits will be used by Ministry of the Environment head office and regional staff and by external consultants. If this approach proves to be inefficient or nonproductive, however, it may be necessary to resort to new or amended legislation which would prescribe mandatory reporting on specified hazardous substances by industrial users.

Whatever the eventual mechanism of data gathering, every effort will be made to avoid duplication of requests to industry by various provincial and federal agencies. The Ontario Ministry of the Environment is working closely with the Ontario Region of the Environmental Protection Service and with the Environmental Contaminants Control Branch in Ottawa to ensure that multiple approaches to industry for the same data will be minimized. The Ministry of the Environment is also working to alleviate this kind of duplication and competition within Ontario, where other ministries of the Provincial Government may eventually collect data on the production and use of toxic industrial chemicals.

Description of the Hazardous Substances Handbook:

The Hazardous Substances Handbook (MOE Report #ARB-TDA-33-76) consists of the Hazardous Substances List and various supplementary materials which are intended to provide background information to assist in collecting inventory data and assessing potential emissions. The data sheets on properties, regulations, uses etc. for each entry of HASL provide only very basic information. These sheets are not exhaustive compilations of recent scientific findings but are instead summaries of a few pertinent data from standard reference sources. Comments based on reading of the current literature and on the extensive files accumulates since the start of the programme have been added to the data sheets to indicate important aspects or to place the given information in context.

Conclusion:

It is clear that cooperation between industry and government regarding control of environmental contamination will cause

fewer headaches in the long term than confrontation and competition. Provincial and federal governments are obliged to inform the public about the chemical hazards to which they may be exposed. As corporate citizens, industries should feel an obligation to inform their community neighbours about the nature of potentially hazardous discharges. The Ministry of the Environment recognizes its responsibility to identify and control hazardous situations created by toxic industrial discharges. Industry must recognize this social responsibility as well.

Major chemical companies have already recognized that long-term plans to identify, control and alleviate worker and community exposure to hazardous substances are essential to their own planning processes. Among many programmes now underway, commitments of this sort have been made by Dow Chemical ("Product Stewardship" programme), Union Carbide, Rohm and Haas, and Dupont, to name a few.

The Hazardous Substances Programme will establish contact with a number of trade associations and industry head offices to enlist their cooperation in determining names, locations, and quantities of substances which could be hazardous to human health and the environment, were they to be released in small quantities during manufacture, processing, storage, transportation, use, or disposal.

Industrial trade associations can play a major role at the interface between government and individual industrial companies. The objective of the Hazardous Substances Programme have been explained to many industrial groups, and support has been given by, for example, the Lambton Industrial Society, the Canadian Chemical Specialities Producers Association, the Society of the Plastics Industry (Canada), and several others.

Government and industry must share the responsibility of controlling chemical hazards, for the implications of the exposure of future generations of humans and other living things to accumulating environmental contaminants are awesome if controls are not begun immediately. Mutual responsibility is the key to the success of the Hazardous Substances Programme, whose major objectives are to anticipate hazards and to prevent crisis situations.

FIGURE 1.

Hazard Rating Checklist (HARC)
MOE Hazardous Substances Programme

INSTRUCTIONS:

Rate each substance on a separate form. On the basis of your current knowledge of the various aspects of each substance described by the criteria (descriptors) in the checklist below, assign a rating value between the limits indicated. Tick (✓) those descriptors which influenced your rating in each category. Please circle the letter (A,B,C,D) or letters preceding the categories of descriptors about which you have the greatest knowledge.

Name of Substance(s) Rated:

Score	Category
	A. Human Health Effects (0 - 40 Points)
☐	General Environmental Exposure Effects
☐	Long-Term (Chronic) Effects
☐	Carcinogenesis
☐	Mutagenesis
☐	Teratogenesis
☐	Neuropathy
☐	Acute Effects
☐	Occupational Exposure Effects (Known Episodes, etc.)
	B. Environmental Impact (0 - 25 Points)
	Non-Human Biological Effects (Experimental or Known Episodes)
☐	Phytotoxicity
☐	Toxicity to Aquatic Life
☐	Toxicity to Other Animal Life
☐	Ecological Systemic Effects/Synergisms
☐	Effects on Inanimate Materials (Corrosion, etc.)
	Chemical Dynamics
☐	Persistence
☐	Environmental Chemistry/Transformations
☐	Water
☐	Air
☐	Soil
☐	Baseline Concentrations/Natural or Existing Background
	C. Discharges to the Environment (0 - 20 Points)
	Industrial/Municipal
☐	Quantities Present
☐	Concentrations in Discharges (measured or estimated)
☐	End Use or Disposal (including transporation, storage, etc.)
☐	Accident Potential for Release to the Environment
☐	Diffuse Sources (landfills, consumer product use, etc.)
	D. Social and Econimic Impact (0 - 15 Points)
☐	Exposed Population (size, sensitivity)
☐	Effected Geographic Area (size, sensitivity)
☐	Social Costs (health care, etc.)
☐	Abatement and Control Costs
	TOTAL SCORE

TABLE 1.

Ministry of the Environment Priority Chemical Substances

Category A Higher Priority	Category B Lower Priority
arsenic (antimony, selenium, tellurium)	polyhalogenated biphenyls
polycyclic aromatic hydrocarbons	asbestos
halogenated aromatic hydrocarbons	lead
mercury	phenols
radionuclides	phthalic esters
nickel (zinc, chromium, cadmium)	acrylamide (+related compounds)
vinyl chloride	ammonia
halogenated aliphatic hydrocarbons	nitrosamines
aromatic hydrocarbons	bromine
aromatic amines	nitrogen oxides and nitrates
chlorine and chlorine dioxide	hydrazine (+ related compounds)
	ozone

"OCCUPATIONAL HEALTH NEEDS OF ONTARIO"

by

Dr. Rodney May

While commenting on the current situation in Ontario, Dr. May outlined his perception of where the problem areas are by drawing on his past experience in the United Kingdom, Europe, Nova Scotia and Alberta. He spoke about the close relationship between occupational health and occupation safety and how management, labor and government must work together in an effort to identify, eliminate and prevent health hazards in the workplace.

Dr. May explained the history behind the establishment of the new Occupational Health and Safety Division of the Ministry of Labour, its role and objectives and commented on the philosophy behind the new Health and Safety Legislation that is being developed by that Ministry in consultation with the various groups affected.

Note: Additional details on this paper may be obtained from the author.

MEMO FROM:

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GROUND WATER CONTAMINATION AND ITS CONTROL

by

G. M. Hughes

Introduction

The field of ground-water flow and contaminant transport has grown rapidly in recent years. This growth has been in response to an increasing need for ground-water supplies, a need for the evaluation of ground-water resources as input to regional planning and interest on the part of environmental groups and government in protecting these ground-water resources from contamination.

Concern for ground-water contamination has become a major obstacle to many waste disposal projects in Ontario; in particular to sanitary landfilling. Much of this is due to a lack of understanding of this subject by lay people and even by professionals. In this presentation I would therefore like to review some of the basics of ground-water flow, describe how contaminants are introduced into and move with the ground water, give some examples of ground-water contamination problems in Ontario, and suggest some solutions to these problems.

Ground Water Flow

Figure 1 illustrates diagrammatically the hydrologic cycle and a ground-water flow system in a climate such as that of Ontario's. The basic elements of the hydrologic cycle are precipitation, evapotranspiration, runoff and infiltration. Infiltration is the element of most concern to the hydrogeologist as it is this water which recharges and replenishes the ground-water reservoir.

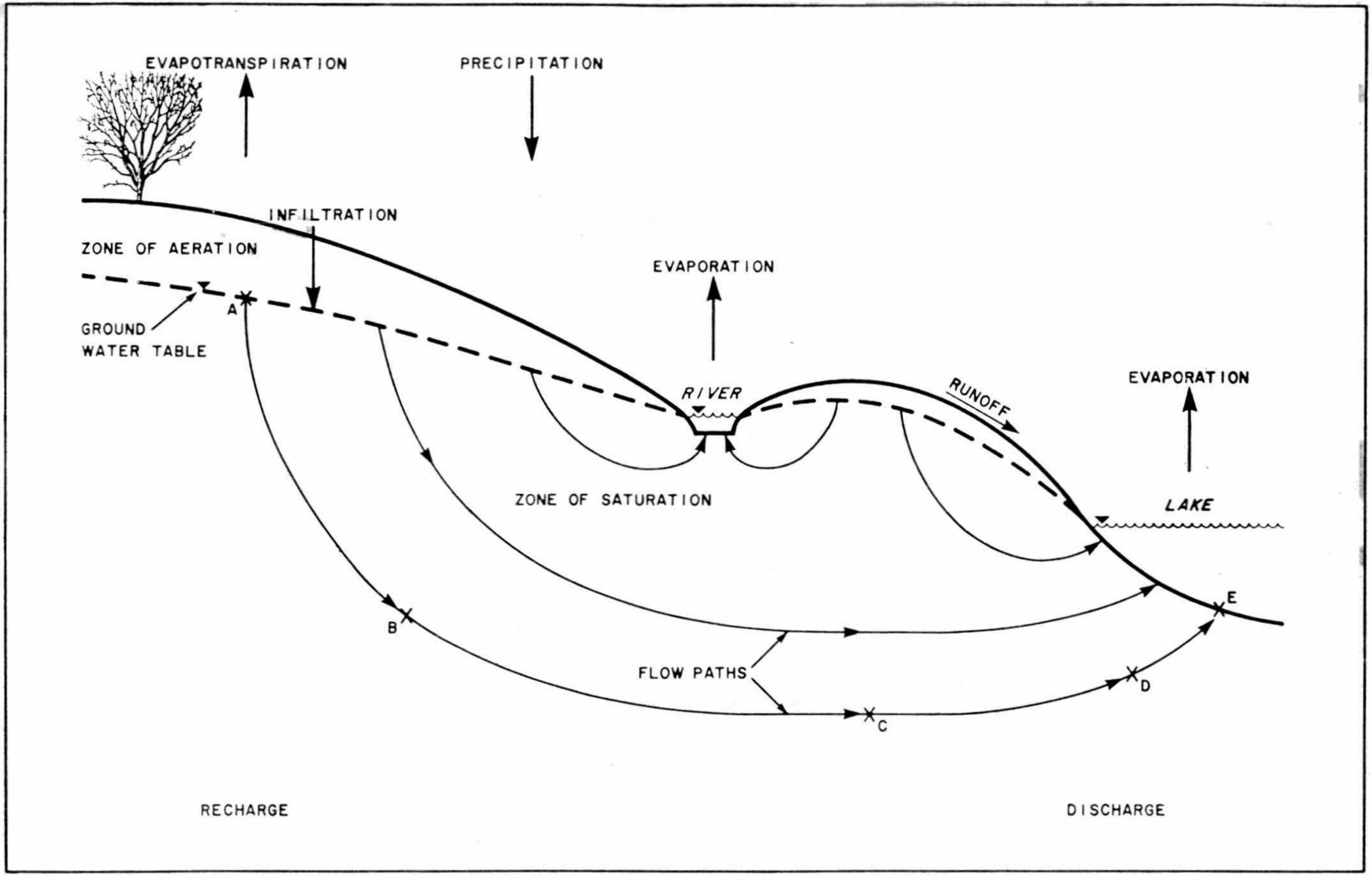


FIGURE 1 - THE HYDROLOGIC CYCLE AND GROUND WATER FLOW SYSTEM

As shown in Figure 1, infiltration moves downward through the unsaturated zone to the water table and then enters the zone of saturation and becomes ground water.

For practical purposes the water table is the upper boundary of the zone below which all of the void spaces in the soil or rock are filled with water. The water table is not necessarily the level at which water can be seen moving into an excavation or boring. If earth materials such as clays are present, an excavation may extend well below the water table and, still maintain "dry" working conditions. This is because seepage water is evaporated as rapidly as it moves into the excavation.

The water table is not synonymous with the term aquifer. Most hydrogeologists consider an aquifer as a "useful source of ground water". Depending on the circumstances, this may be a thick sand unit capable of yielding 1,000 gpm to a well or a thin silt capable of yielding only 1 gpm.

After reaching the water table, infiltration moves into a ground-water flow system and follows a predetermined path to eventually discharge at the ground surface. In Figure 1 line A, B, C, D, E illustrates such a flow path in a hypothetical ground-water flow system. This flow path is determined by the following factors:

(a) The quantity of water moving through the flow system. This is related to the amount of ground-water recharge.

(b) The gradient available to move this water. This is related to the difference in elevation between the point where the ground water

enters the system, and the point where the ground water leaves the system. Incidently this discharging ground water is the source of baseflow to our streams and the water in our permanent lakes and swamps.

(c) The permeability, thickness and distribution of the various earth materials through which the water moves in this system. Permeability is defined as "the capacity of an earth material for transmitting a fluid"*.

(Permeability is not the same as porosity which is defined as "the ratio of aggregate volume of interstices in a rock or soil to its total volume".* For example, clays have relatively low permeability but high porosity. Sands and gravels have lower porosities than clays but their permeabilities are orders of magnitude higher. Ground water may move tens of feet per year through sand and gravel deposits but only fractions of a foot per year through unfractured clays).

In Figure 1 water enters the ground-water flow system at A in what is called a ground-water recharge area. This water moves along the flow line past points B, C and D to discharge, in a ground-water discharge area, into the lake at E. We know that this is the path followed by the water because we can measure a decline in head (as reflected by water levels in wells) along this flow line from A to B to C to D and to E.

Two points are illustrated by Figure 1:

(a) The water level in wells may not necessarily reflect the elevation

* The Glossary of Geology and Related Sciences, Second Addition, Amer. Geological Institute, 2101 Constitution Avenue, N.W., Washington 25, D.C.

of the water table. Only at points A and E along flow line A, B, C, D, E, would the water level in a well be at the same elevation as the water table.

(b) The ground-water flow system as shown in Figure 1 is a system in equilibrium. A gradient has developed which is just adequate to move the amount of water which infiltrates into the system along a particular flow path through materials with a particular permeability. This gradient is reflected by the elevation of the water table. In wet years, the water table rises, the ground-water gradient increases and more water moves through the system. If we change one of the factors in this system, as for example by developing a well field, the system must respond to compensate for this change.

The Movement of Contaminants With the Ground Water

Dissolved solids (or contaminants) introduced at or near the ground surface move downward with infiltration to the water table and then into the ground-water flow system. A mass of contaminated water moving in the sub-surface is called a contaminant plume. Figures 2 and 3 are simplified illustrations of a contaminant plume which has developed beneath a landfill site at CFB Borden. Note that the contaminants are not concentrated along the top of the zone of saturation nor at the bottom at the aquifer, but form a distinct three-dimensional unit in the sub-surface.

The shape and extent of a contaminant plume depends on many factors. Some of these factors act to remove the dissolved solids from the

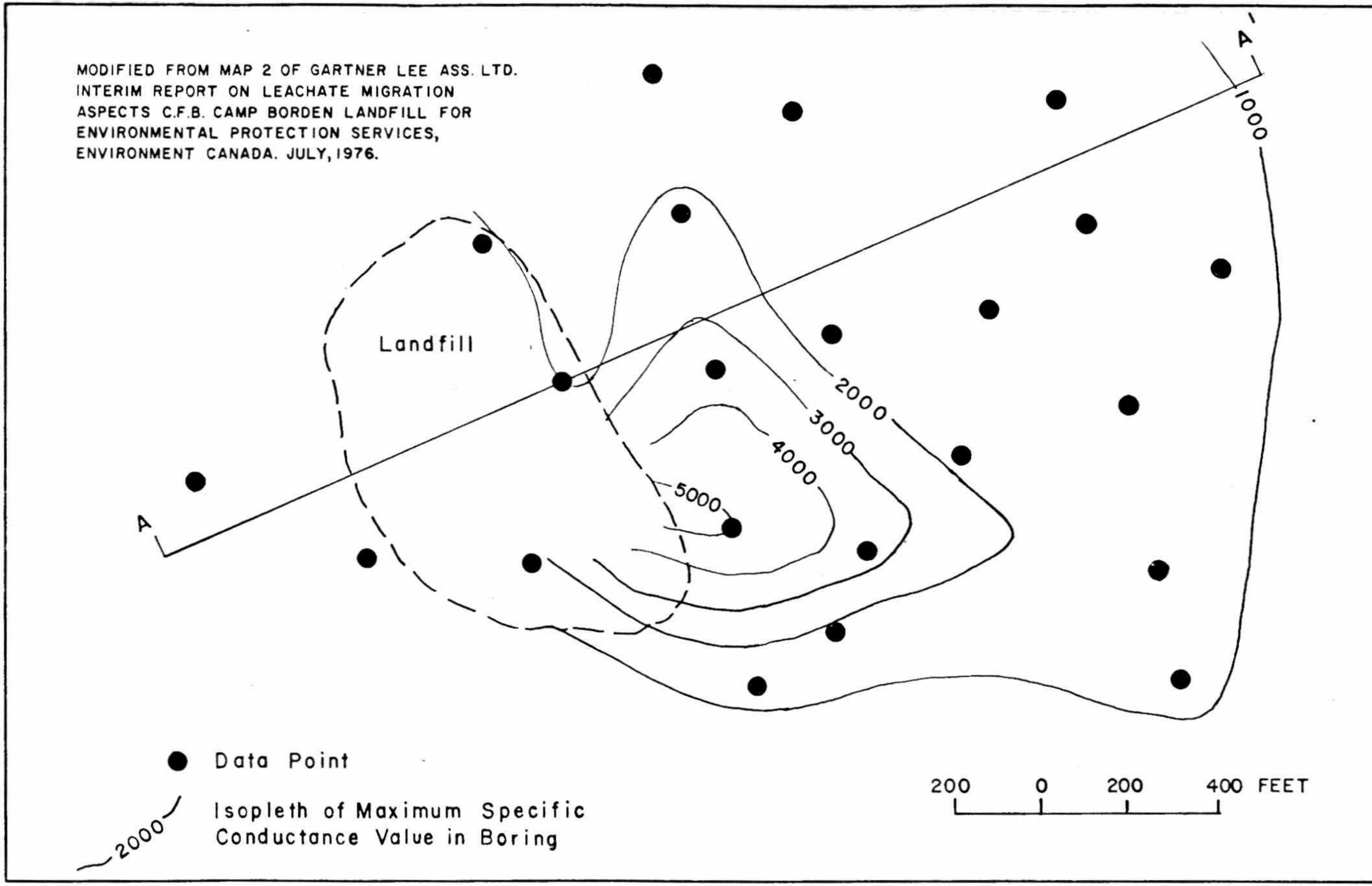


FIGURE 2 - PLAN VIEW OF CONTAMINANT PLUME

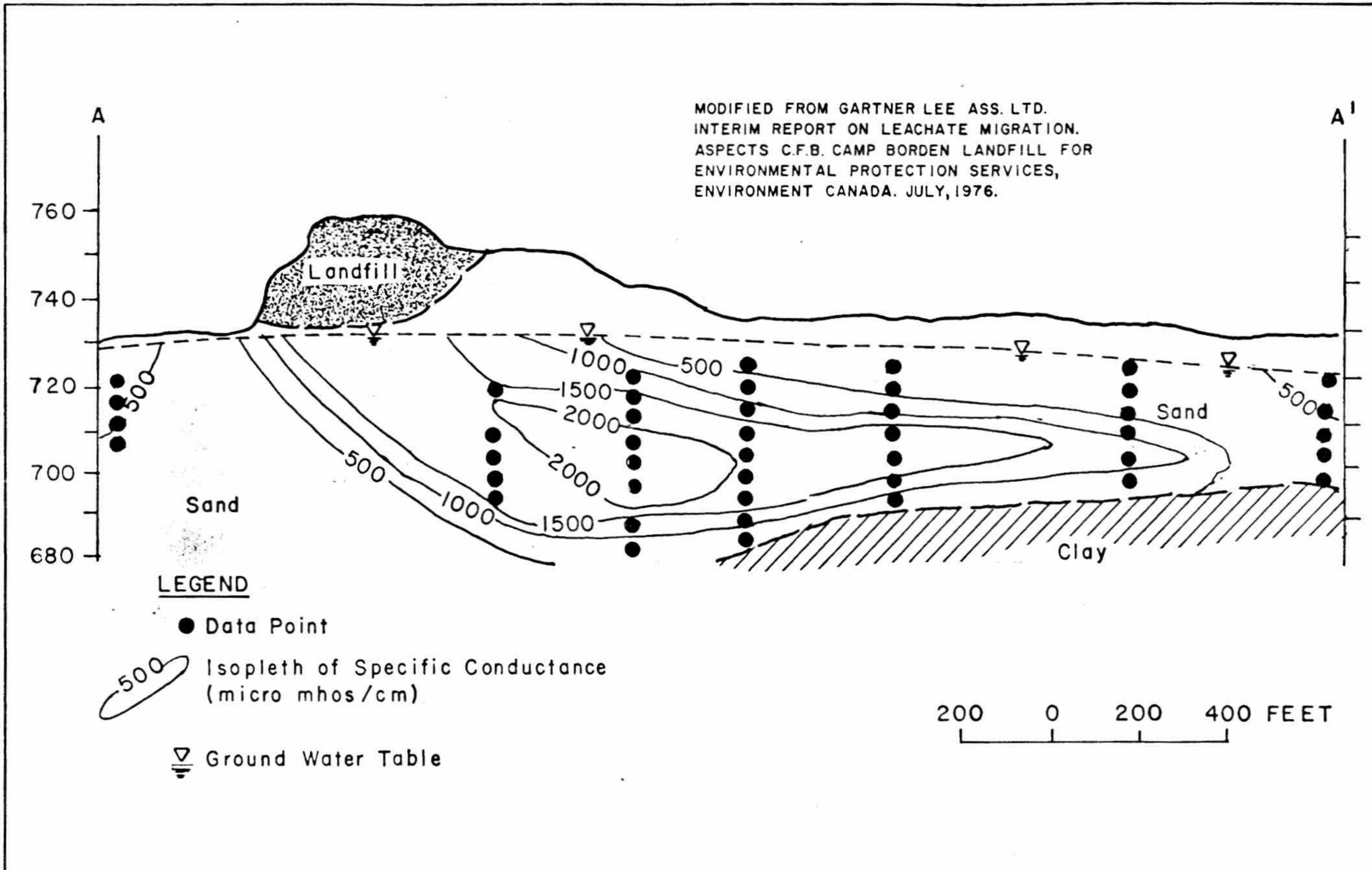


FIGURE 3 - CROSS SECTION OF CONTAMINANT PLUME

ground water, others to disperse and dilute these dissolved solids.

Table 1 lists the physical, chemical and biological processes which are
attenuate contaminants include mechanical filtration, pptn and co-pptn, sorption, gaseous exchange, dilution and disperation and microbial activity.
involved. Table 2 expands on the contribution to attenuation which

could be made by the "soil" microbial community (i.e the biologic
include mineralization, immobilization, oxidation, reduction, fixation, geological deposit formation, production or organic volatilization or chelating or complexing agents, adsorption and isotope fractionation.
processes). Nor all of the processes listed in tables 1 and 2 are
completely understood and as yet few can be accurately quantified.

A critical factor in determining the configuration of a contaminant plume is the velocity at which ground water moves. This is because the biological and many of the chemical processes, which act to attenuate ground-water contaminants, are time dependent; therefore, rapid ground-water movement may allow contaminants to migrate a proportionately greater distance before they are attenuated.

Ground-water velocity (V) is described by Darcy's Law; a form of which is:

$$V = \frac{KI}{Sy}$$

In this equation K represents permeability,* or the capacity of an earth material for transmitting a fluid. The permeabilities of common earth materials are given in Figure 4.

Permeability is indirectly related to the capacity of the earth materials to attenuate dissolved solids in contaminated ground water. For example, a fine textured material, which generally has a low permeability, also has a large surface area and thereby a great capacity to attenuate contaminants by mechanisms such as sorption.

* Hydraulic conductivity is a more correct term

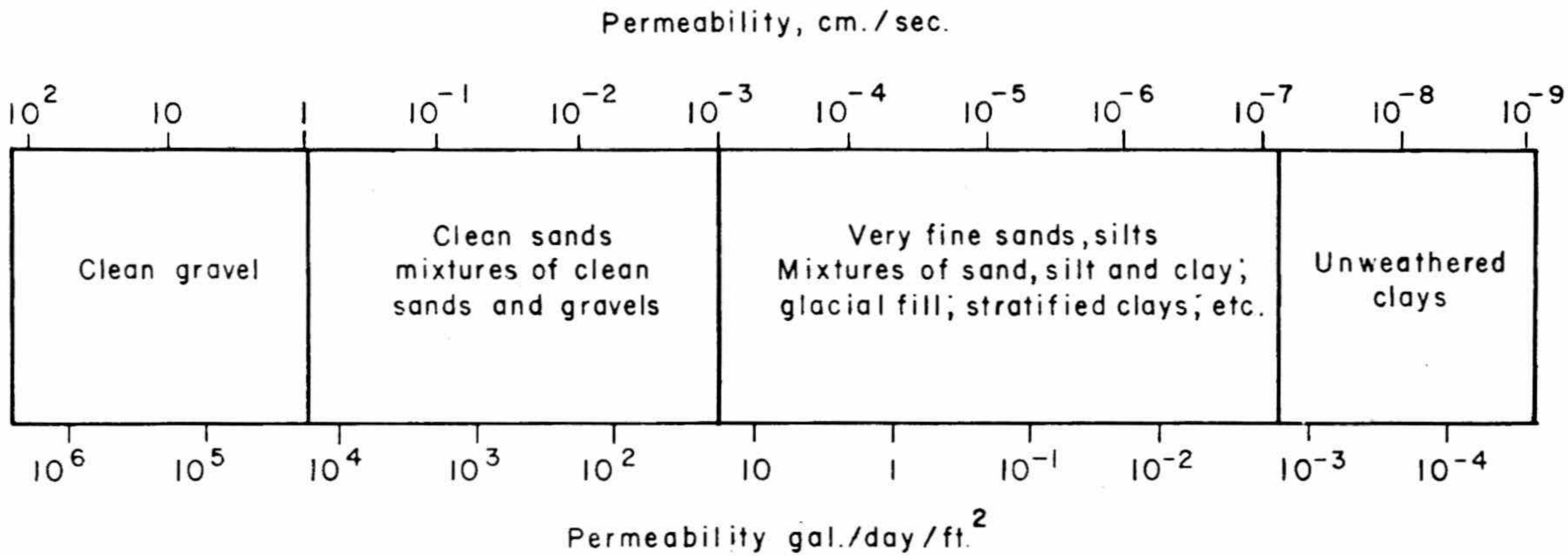
TABLE 1*: The Physical, Chemical and Biological Processes which Attenuate Contaminants

1. Mechanical filtration
2. Precipitation and co-precipitation
3. Sorption
4. Gaseous exchange
5. Dilution and dispersion
6. Microbial activity

TABLE 2*: Contributions to Attenuation by the Soil Microbial Community (Alexander, Martin. "Microbial Ecology", John Wiley & Sons Inc., 1971).

1. Mineralization
2. Immobilization
3. Oxidation
4. Reduction
5. Volatilization or fixation
6. Geological deposit formation
7. Production or organic cholating or complexing agents
8. Adsorption
9. Isotope fractionation

*Farquhar, G.J., and Rovers, F.A., 1976. Leachate Attenuation in Undisturbed and Remoulded Soils, Proceedings of Research Symposium, Rutgers Univ., New Brunswick, New Jersey, March 25 and 26, 1975. EPA-600/9-76-004, March 1976. U.S. EPA, Municipal Environment Research Lab., Cincinnati, Ohio, p. 54-70.



Modified from table on pg 53 of Todd, D, K, 1959,
Ground Water Hydrology. John Wiley & Sons Inc, New York. 336 P

GURE 4 : RANGE IN PERMEABILITY OF DIFFERENT SOIL CLASSES

From the above equation, I represents the ground-water gradient. The ground-water gradient has much the same effect on contaminant movement as does permeability. In hilly areas with high relief, the ground-water gradient is I is likely to be high and V, the velocity of the ground water, correspondingly greater. High gradients are most common in materials that are fine-textured and have low permeabilities.

Also from the equation, the specific yield (also called effective porosity or gravity yield) is defined as that part of the porosity of a rock or soil which can be drained by gravity. As shown in Figure 5, fractured equal, gw will move through rocks have low specific yield. A given amount of water will only fill block A which has intergranular porosity to a., whereas Block B with fracture porosity will be filled to the level shown by b. Other factors being equal, ground water will move through rocks with low specific yield (i.e. fractured rocks) with a greater velocity and subsequently, the attenuation of contaminants in this water will be correspondingly lower than in material with intergranular porosity. In addition, the surface area available for exchange and sorption is much lower in fractured rocks than in rocks with intergranular porosity.

In summary, certain hydrogeologic environments are more susceptible, or sensitive, to ground-water contamination than are others. In evaluating sites for their potential for contamination, the position of the site in the ground-water flow system and the distance contaminants must move to reach a point of water use should be considered. In addition, the presence of rocks with high permeabilities and low specific yields (i.e. fractured rocks) and areas with high ground-water gradients increase the potential for ground-water contamination.

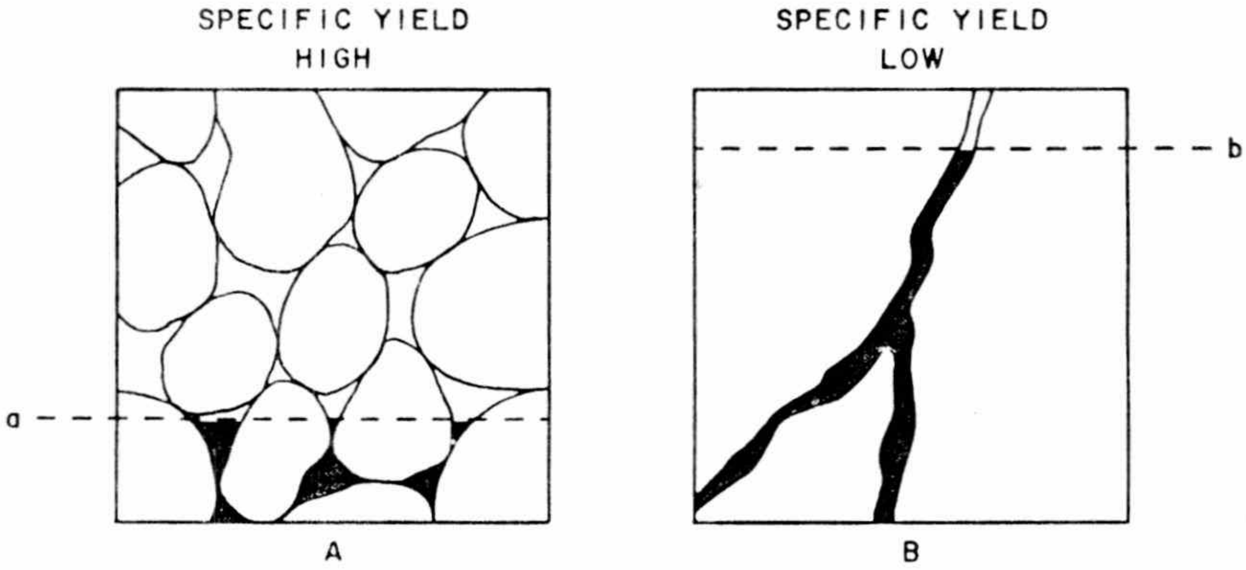


FIGURE 5 - COMPARISON OF INTERGRANULAR (A) AND FRACTURE (B) POROSITY

The Role of the Ministry of the Environment

Ontario

The Ministry of the Environment has two principle functions in the area of ground-water contamination. The Ministry regulates waste disposal activities and acts to clean up, or abate, ground-water contamination caused by unregulated activities, or by accidents.

The regulation and review of designs for waste disposal facilities requires a considerable amount of the Ministry's time. There are comparatively few cases of ground-water contamination caused by waste disposal in Ontario and perhaps because of the work this indicates that the Ministry is doing a good job in regulating waste disposal sites.

With respect to the clean up and abatement of ground-water contamination in Ontario, the our major problems have been associated with deicing chemicals (i.e. road salt) and leaks from buried gasoline and fuel oil storage tanks.

When the Ministry receives a complaint of ground-water contamination, such as a contaminated well, our response is generally as follows:

a visit is paid to the site

a. The site is visited and the well is sampled to determine if the water is contaminated and if so, the type of contamination.

b. An investigation is undertaken to determine the source and the reason for the this contamination. The This reason may be relatively simple, such as surface water leaking into a poorly sealed well or, it may be very complex.

c. If the source of the contamination can be identified, measures are taken to remove that source and to prevent the further spread of the contamination.

d. Methods are recommended for restoring those water supplies that have been contaminated.

A few examples of ground-water contamination cases with which the Ministry has been involved may illustrate our function and limitations. These cases have been selected to show particular difficulties but they are not atypical.

1. Case I

This case (Figure 6) involved fuel oil moving on the ground water into the basement of a private residence. All known sources of fuel oil in the area were investigated and found to be secure. A number of pits were excavated and borings were made; but however, the source of this fuel oil could not be positively determined. It was concluded that the fuel oil originated either from a buried tank that had leaked sometime in the past and had been repaired or from a leak in an undiscovered abandoned tank in the area. Expenditures* to date in this investigation are on the order of \$10-15,000 and continuing The the investigation, showed that to positively define the source of the oil, could involve excavating large quantities of bedrock and soil. The cost involved would depend on what is discovered but would very probably exceed \$5000. The restoration of the basement and blocking the flow of the oil into this basement would cost an estimated \$6500.

The cost of the damage caused by this fuel oil would be the value of the private residence or approximately \$20,000. Here, therefore, is a case where The the costs involved in identifying the source of the contamination would probably exceed the damage being done by these contaminants and it would be difficult to justify further expenditures towards identifying this source.

* Personal communication, R. Amell, Ministry of the Environment

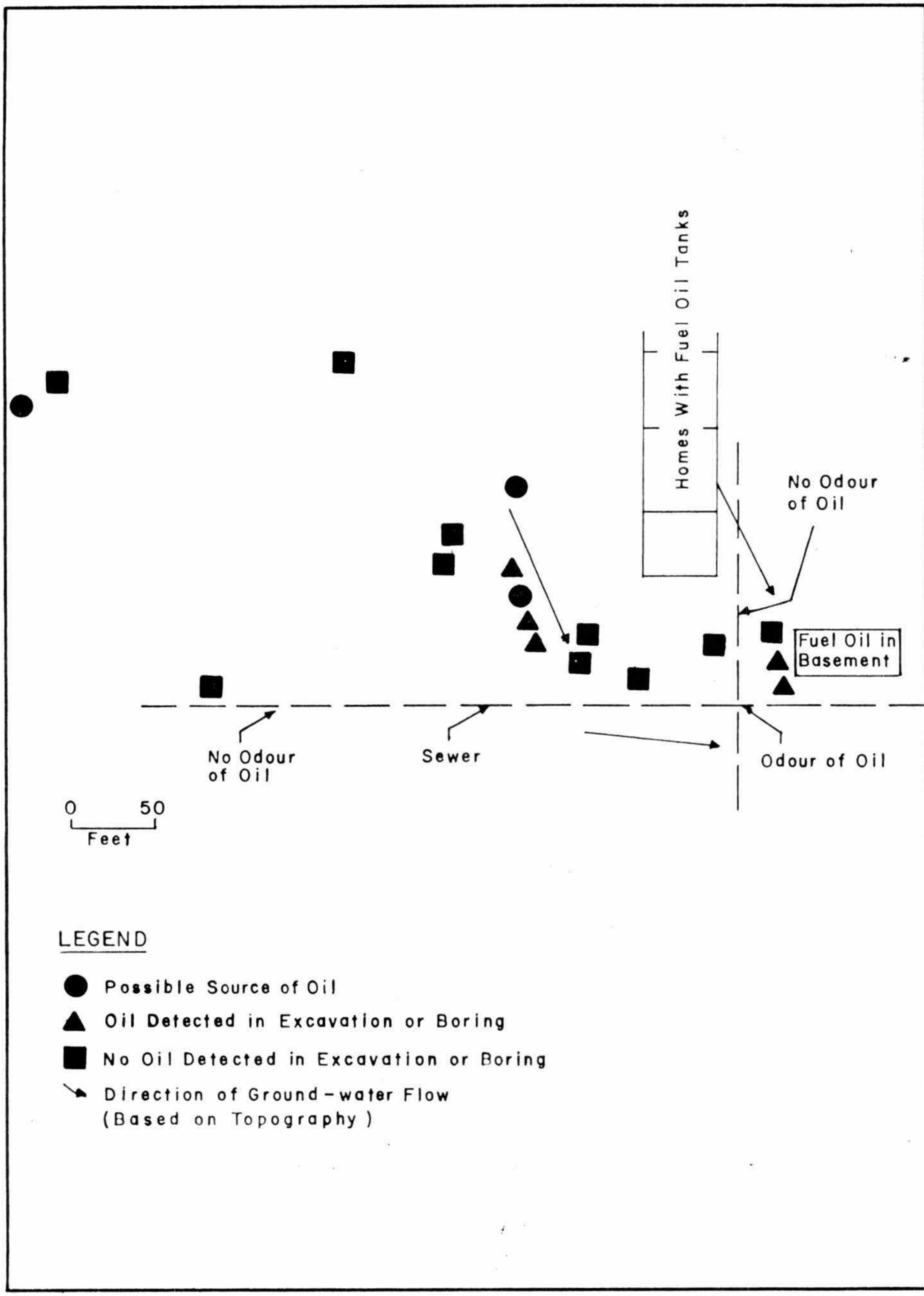


FIGURE 6: GROUND WATER CONTAMINATION CASE I

2. Case II

A

The second example (Figure 7) involves gasoline contamination in four wells in a small village. This investigation identified turned up six possible sources for this gasoline. No one source could be positively related to a particular contaminated well nor could a single source, or for that matter two sources, account for the distribution of gasoline in the subsurface.

This investigation has extended over a period of approximately five years and has cost an estimated $10,000. In this case, the best the Ministry could achieve was to make sure that all existing gasoline storage facilities were secure and to recommend that the owners of the affected wells install charcoal filters.

3. Case III

In this case (Figure 8) a number of several wells in a subdivision were contaminated by salt. The Ministry determined the cause of this contamination to be a sand/salt storage pile and asked that the salt pile be removed. This was done; however, but it was found that the soil beneath the sand/salt pile and downgradient from this pile had been saturated with salt and the salt which continued to be leached into the aquifer. Eventually all of this salt will be flushed from the soil and the aquifer; however, but in the 3 years which have passed since the pile was removed, the concentration of chlorides in some of the contaminated wells still exceeds 250 mg/l ppm, which is the recommended limit for public water supplies in Ontario.

The best solution to this problem would be to obtain another source of water for the homeowners involved, at least until natural processes

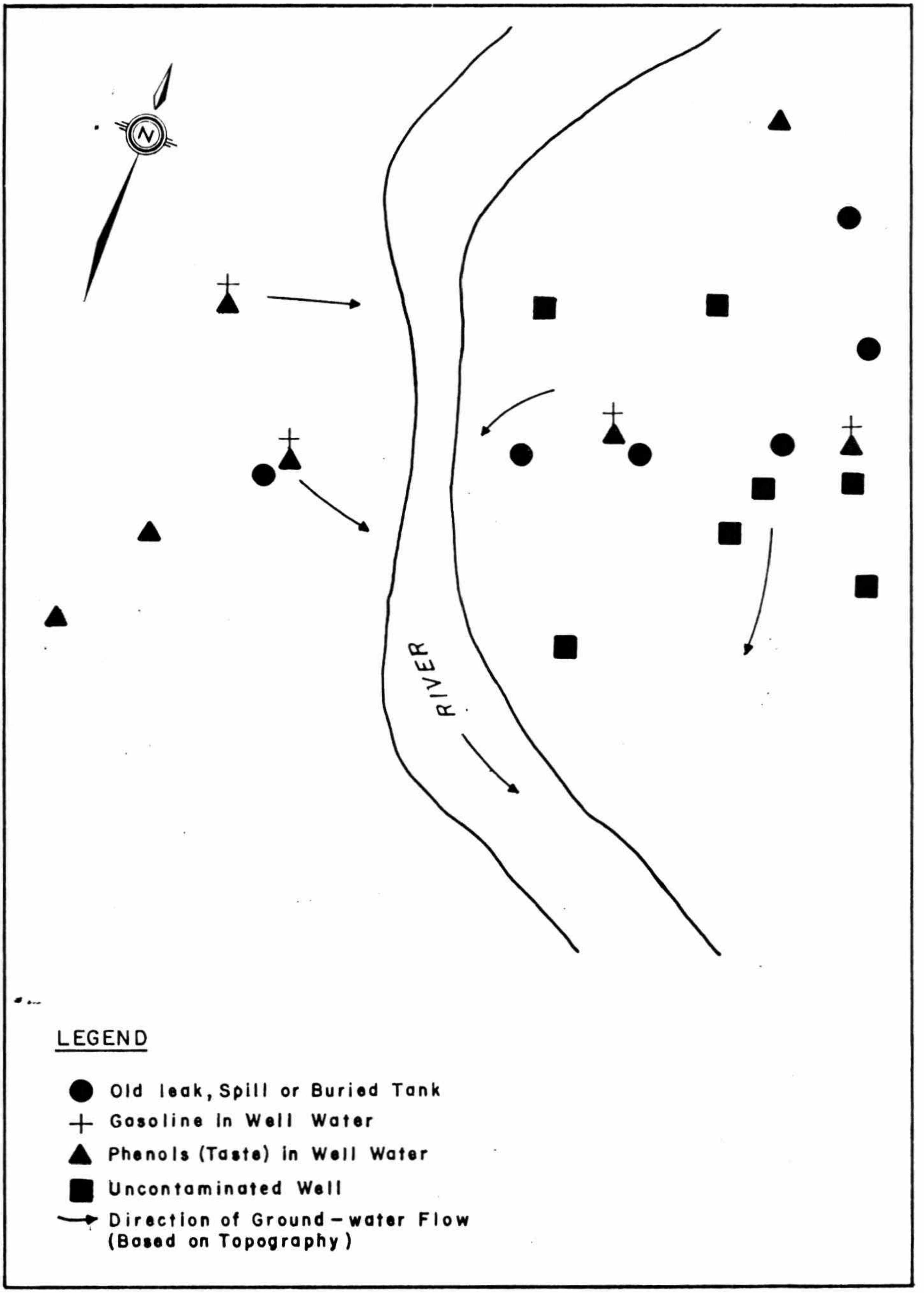


FIGURE 7: GROUND WATER CONTAMINATION, CASE 2

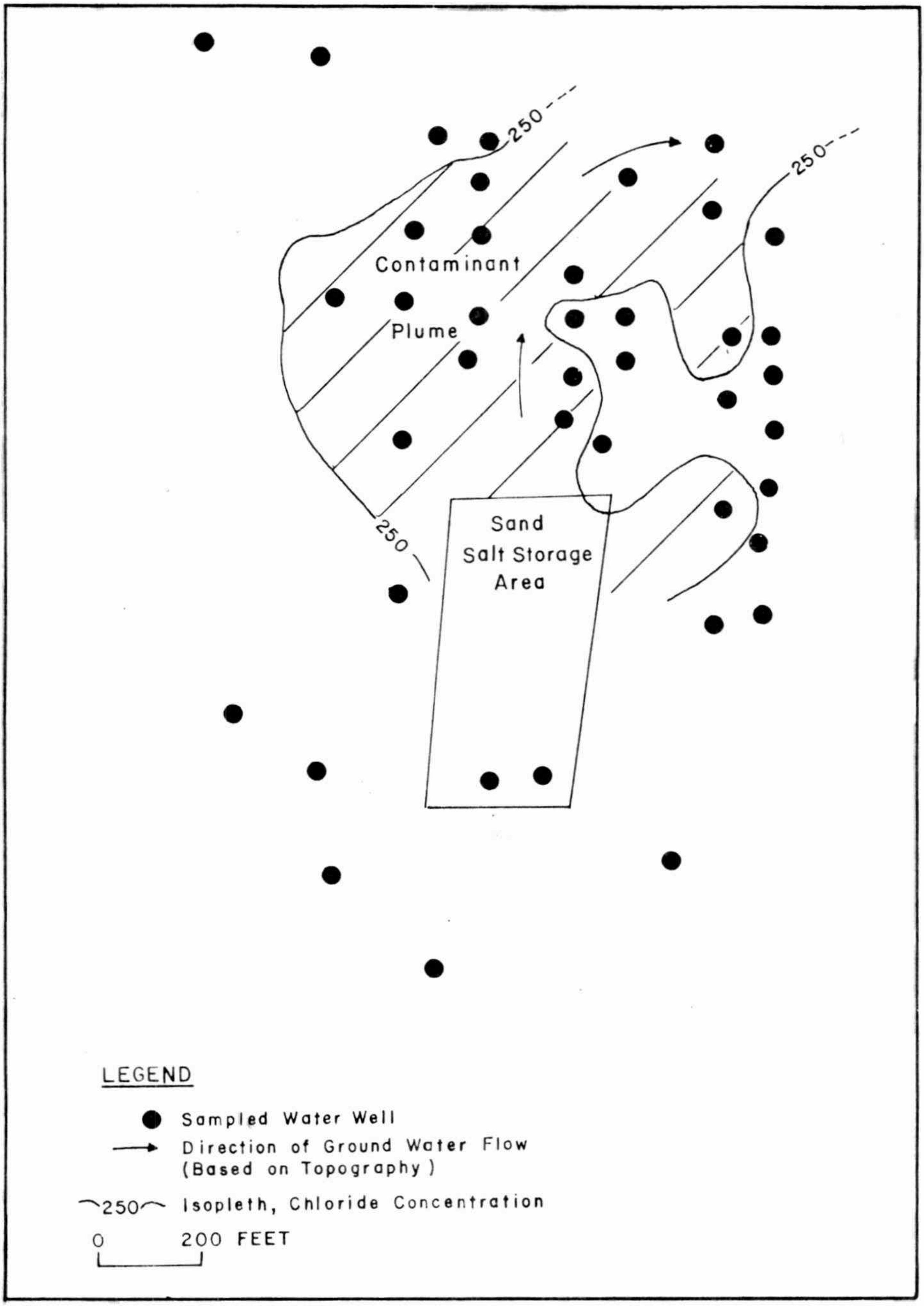


FIGURE 8 : GROUND WATER CONTAMINATION CASE 3

flush the salt from this aquifer. This would be an expensive procedure however and before the courts would be able to determine who should pay for the new water supply, the problem could clear up naturally.

4. Case IV

In a case that

This case (Figure 9) also involves ground-water contamination from a sand/salt storage area. Here vegetation was killed and two wells were contaminated downgradient from this storage area. In this particular case, the problem was resolved by directing surface runoff from the storage area into a nearby creek. Flow in this creek is adequate to dilute the contaminated runoff to acceptable levels.

the The Flow

Procedures and Costs on Ground Water Contamination Clean Ups

The

It is apparent from the foregoing that the resolution of ground-water contamination problems may be relatively difficult. and

is always likely to be

Clean

Clean-up operations will depend on the type of contaminant and the hydrogeology of the site. No two cases will be exactly alike and it is beyond the scope of this paper to discuss, except in a very general way, the methods used to clean up contaminated ground water. Specialists in this field are available and should be contacted when problems arise.

but there are

There are generally two stages to a ground-water contamination clean up operation:

Stage 1 - Remove contaminating material from the ground surface, sorbed on the soils, or concentrated in the ground water. This is usually accomplished by excavating contaminated soils with a backhoe or a bulldozer and by pumping contaminants from ditches or from

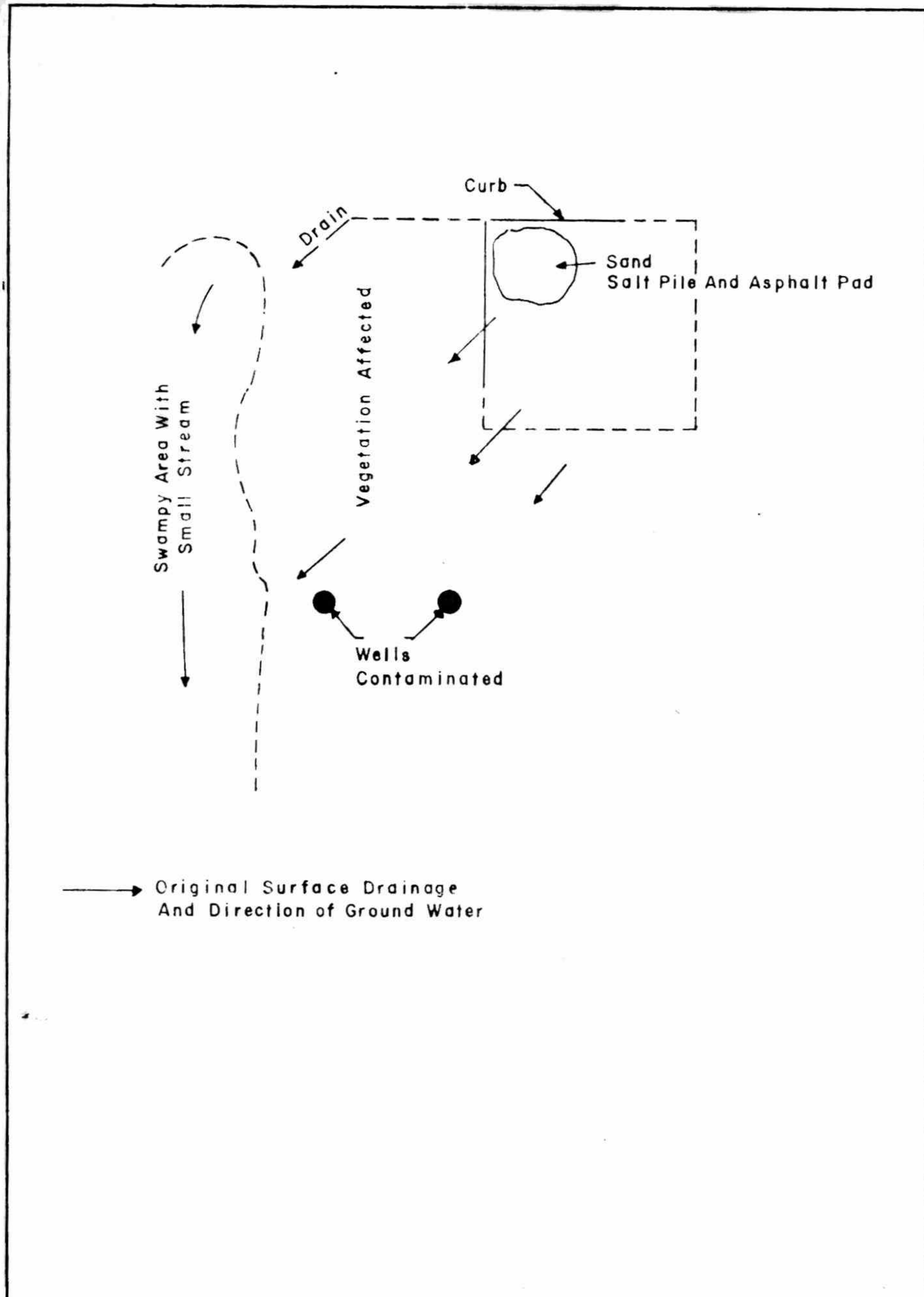


FIGURE 9 : GROUND WATER CONTAMINATION CASE 4

shallow deposits where they are concentrated. In the case of spills particularily in permeable soils or rocks this clean up should proceed as rapidly as possible to minimize the affected area. Rapid action will not, however, appreciably reduce the spread of contaminants which have been introduced into the subsurface over a protracted time period.

Stage 2 - Remove dispersed and diluted contaminants from the aquifer. This commonly involves prolonged pumping of large quantities of water and there are often problems in finding a place to dispose of this contaminated water.

The extent to which these clean up procedures are carried depends on the following factors:

a. The cost of the clean up,

b. the The cost if the contaminants are not cleaned up, and

c. the The availability of funds.

Not only should a The source should be determined and responsibility be assigned, and but there is also some obligation to make the costs of clean up compatible with the cost of the damage. In some cases, even the expense of investigating to determine the source of the contaminant cannot be justified. Complete clean up of contaminants in ground water will seldom be practical because of the high cost and In in most instances funds are just not available.

Some concept What of these costs is are can be gathered from the fact possible if it is considered that some consultants in the business of cleaning up ground-water contamination use, as a "rule of thumb" for estimating the cost of recovering hydrocarbons from ground water, a cost of $100.00 per gallon of product recovered. Costs estimated[1] at between one to three million dollars were incurred

[1] Personal Communication, R. L. Raymond, Suntech Inc.,Marcus Hook, Pa.

as a result of a spill of gasoline into an aquifer in Pennsylvania and approximately two million dollars in clean up costs[2] have been incurred to date in cleaning an aquifer contaminated by refuse leachate in Delaware. It is estimated that this latter clean up will eventually cost on the order of eight to twenty million dollars.

Although these These cases are not typical in that they involve a complete clean up of a major aquifer, the reasons for such high costs are easily understood. Gasoline can be tasted in water at concentrations of less than 10 parts per billion, and therefore so one gallon of gasoline has the potential of contaminating millions of gallons of water. Other contaminants, such as chlorides, are a problem at concentrations of a few hundred parts per million which makes road salt, by comparison, a relatively innocuous contaminant. On the other hand S some of the "new" organic compounds such as PCB and Mirex are of concern at concentrations in the parts per billion range.

[2] Personal Communication, W. Leis, Roy F. Weston Inc., West Chester, Penna.

Conclusions

The best solution to our problems of ground-water contamination is, of course, prevention. How this can best be accomplished depends upon the source of the potential contaminant (or potential contaminant). There are three possible sources; waste disposal (or regulated) activities, unregulated activities, and accidents and leaks.

Waste Disposal Activities - Included here would be disposal of wastes by septic systems, landfilling, sewage sprinkling and spreading operations. These activities are regulated in Ontario and there are mechanisms available to prevent contamination arising from them. We should not have ground-water contamination problems in this area and for the most part we do not.

Unregulated Activities - In this category that are sources of contamination include such as sand/salt storage piles, road salting and fertilizers. These activities may cause significant amounts of ground-water contamination. They are not now regulated and in most instances any regulations would be extremely difficult to accomplish. This is because regulations would affect the public welfare (agriculture) or public safety (road salting). However, if we wish to control ground-water contamination from these activities, is to be controlled some form of regulation will be necessary. Perhaps such regulation would apply only to areas particularly sensitive to ground-water contamination or perhaps and it would might make it easier for compensation to be obtained by those who are affected by such contamination.

Accidents and Leaks - Accidents are "people problems" and thus cannot be completely eliminated. However with proper legislation and public education and with adequate contingency planning, it should be possible

to substantially reduce the number of accidents and their adverse effect on the environment. A contingency plan is of great value in dealing with such problems as leaks in facilities for the bulk storage of liquids and in pipe lines. Such a plan will insure a rapid, organized response by experts with the proper equipment.

Legislation which requires that the Ministry of the Environment be notified in the event of an accidental spill is enforced in Ontario under the Environmental Protection Act. The existing legislation requiring the clean up of such spills is currently under review.

It is my understanding that the Ministry of the Environment is currently developing guidelines with regard to contingency plans for bulk storage facilities. Regulations in this particular area, however, seem to be some distance in the future.

In a somewhat separate category are buried gasoline and fuel oil storage facilities. Post-1974 buried gasoline storage facilities at retail outlets are probably adequately controlled by the Gasoline Handling Act and Code. This is administered by the Ministry of Consumer and Commercial Relations. There are concerns however, for older gasoline storage facilities and for buried fuel oil storage facilities. The Ministry of the Environment, the private sector and the Ministry of Consumer and Commercial Relations are all working to develop adequate regulations and controls for facilities such as this.

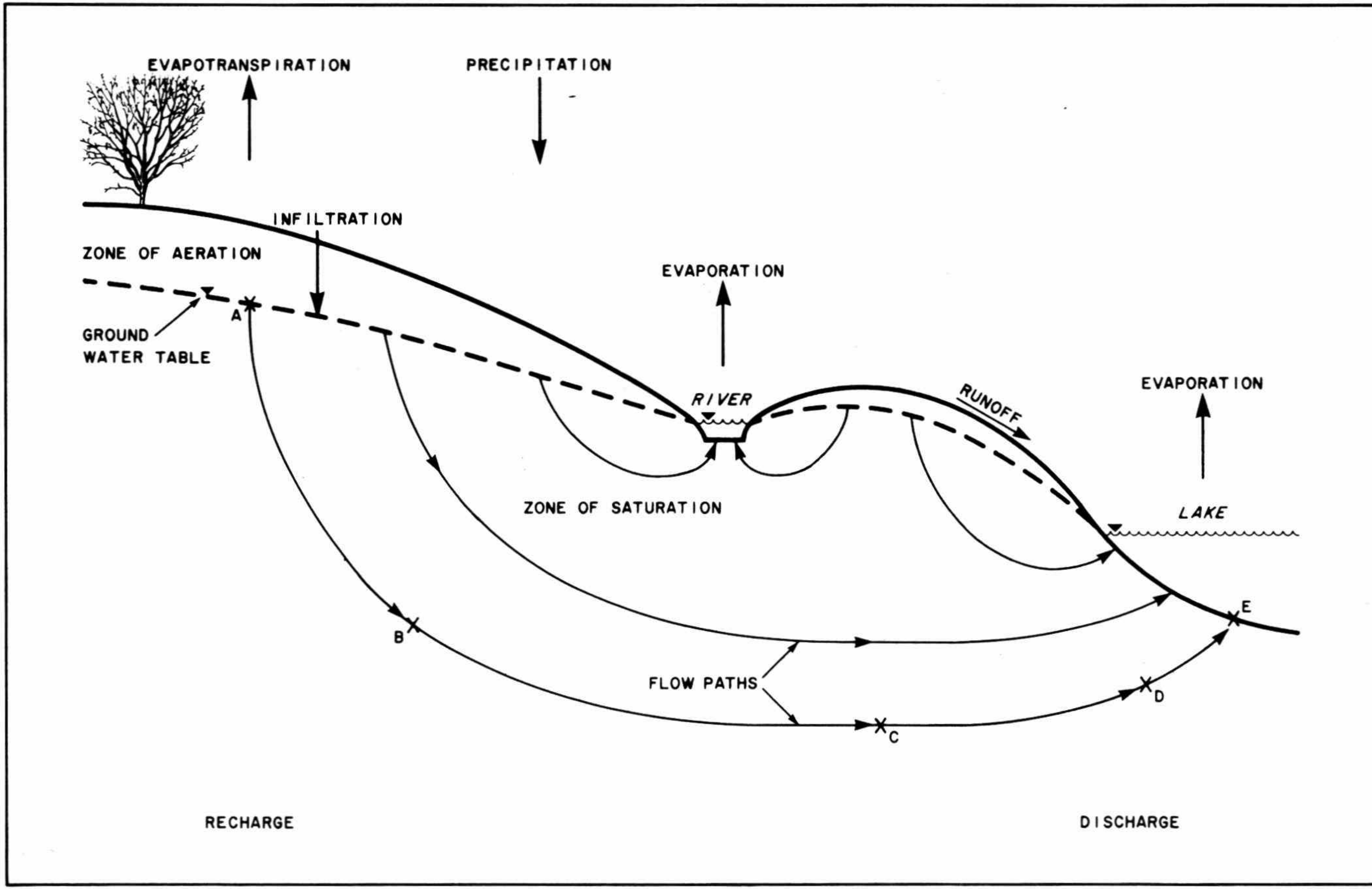


FIGURE I - THE HYDROLOGIC CYCLE AND GROUND WATER FLOW SYSTEM

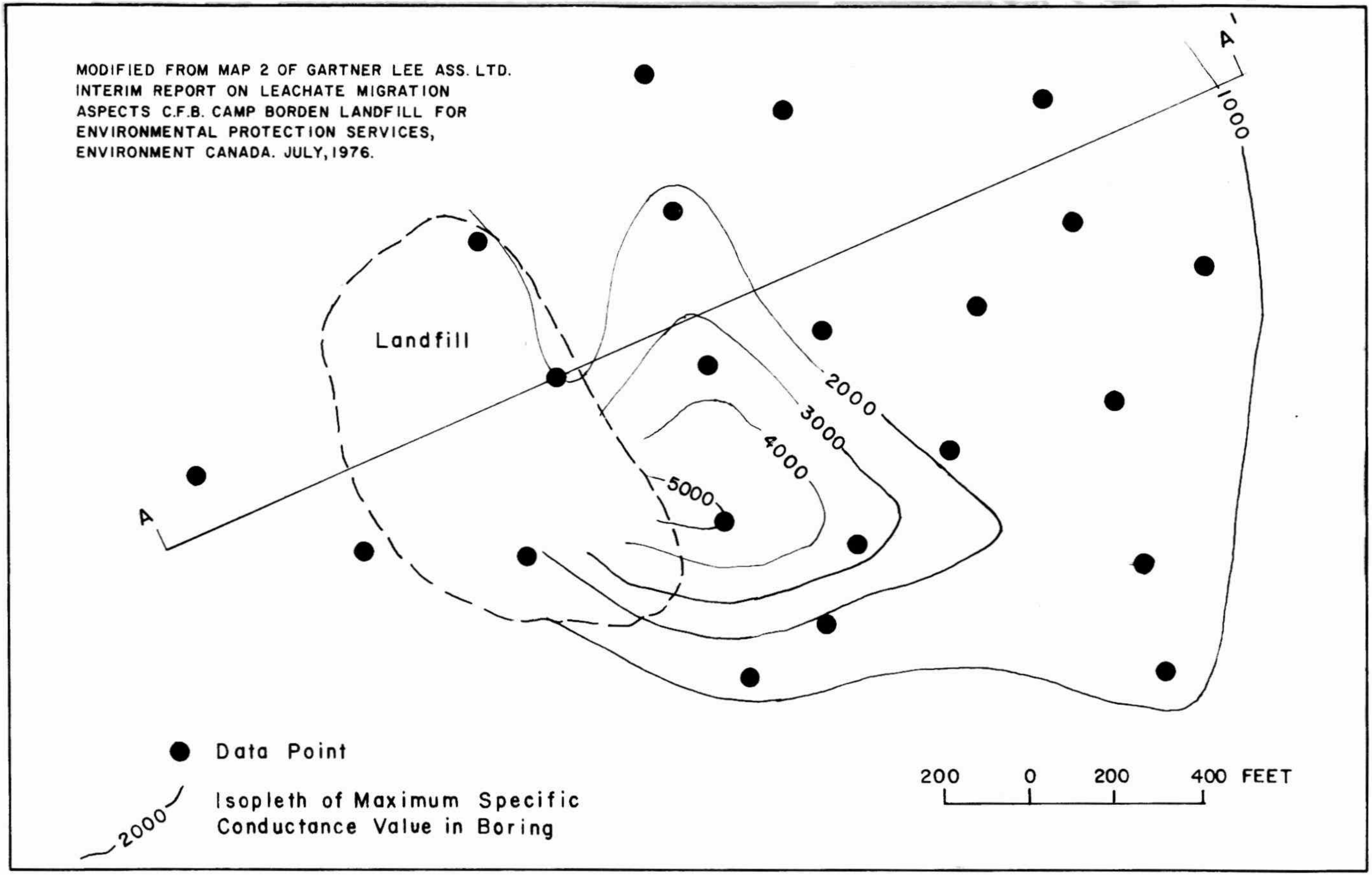


FIGURE 2 - PLAN VIEW OF CONTAMINANT PLUME

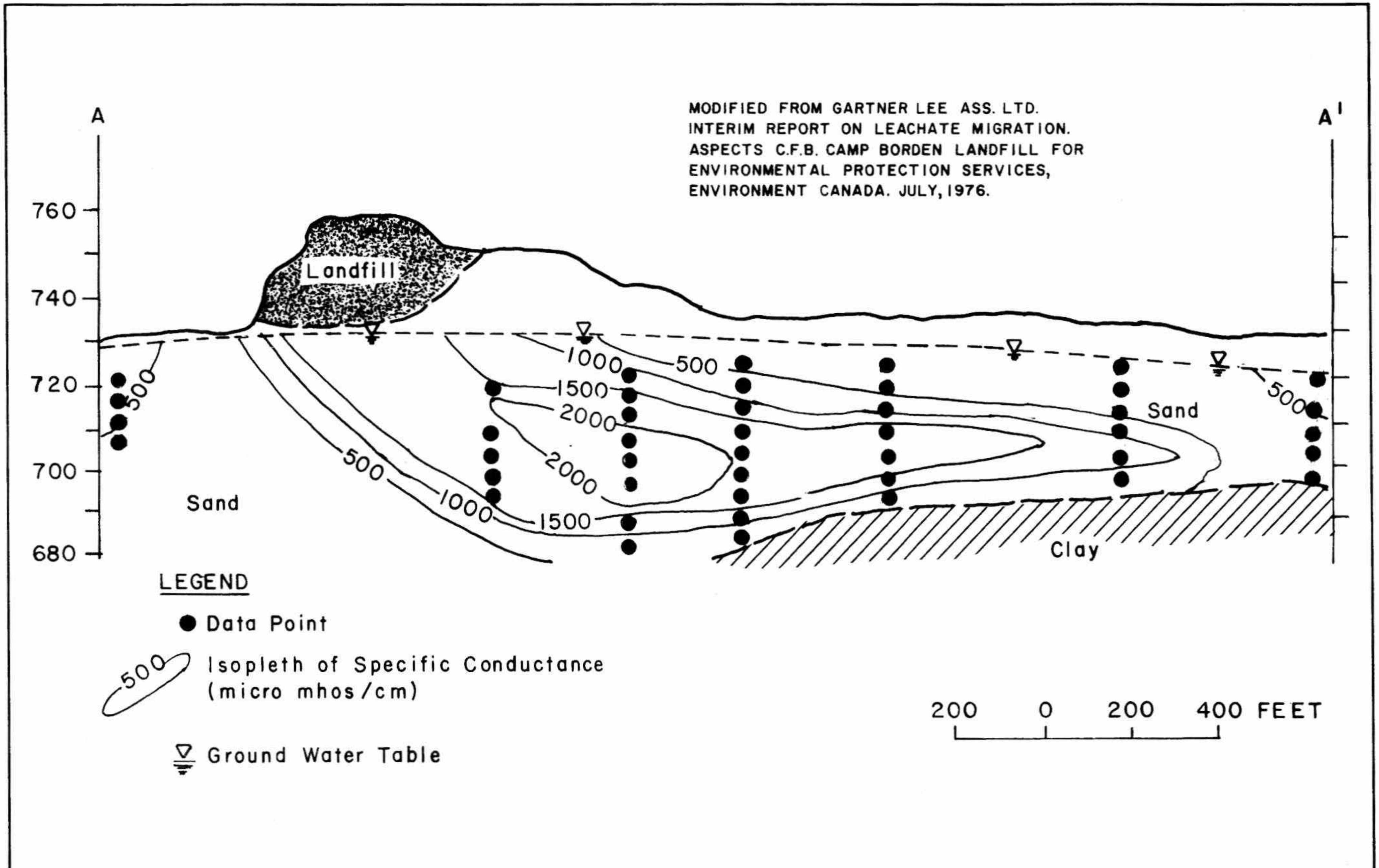
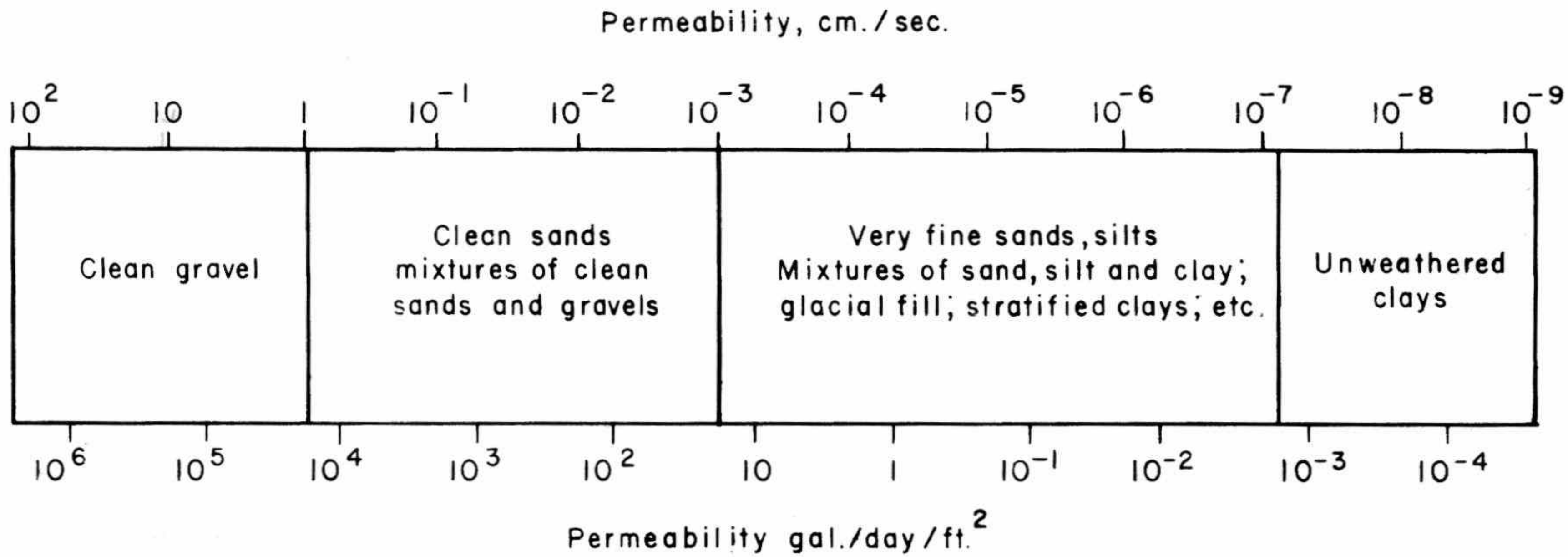


FIGURE 3 – CROSS SECTION OF CONTAMINANT PLUME



Modified from table on pg 53 of Todd, D, K, 1959, Ground Water Hydrology. John Wiley & Sons Inc, New York. 336 P

FIGURE 4 : RANGE IN PERMEABILITY OF DIFFERENT SOIL CLASSES

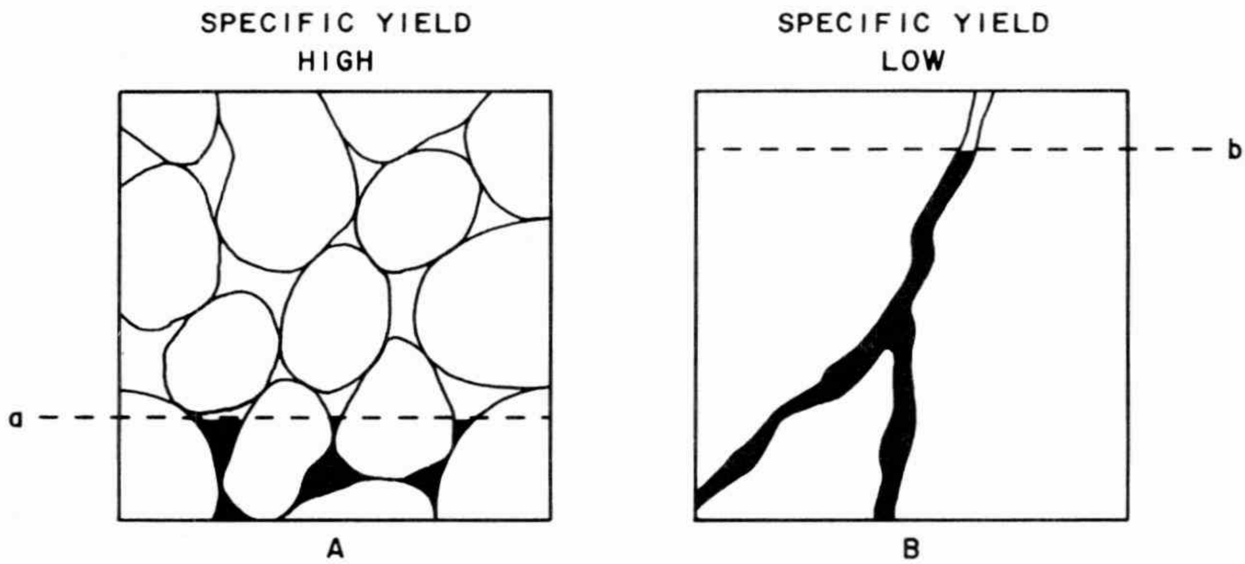


FIGURE 5 - COMPARISON OF INTERGRANULAR (A) AND FRACTURE (B) POROSITY

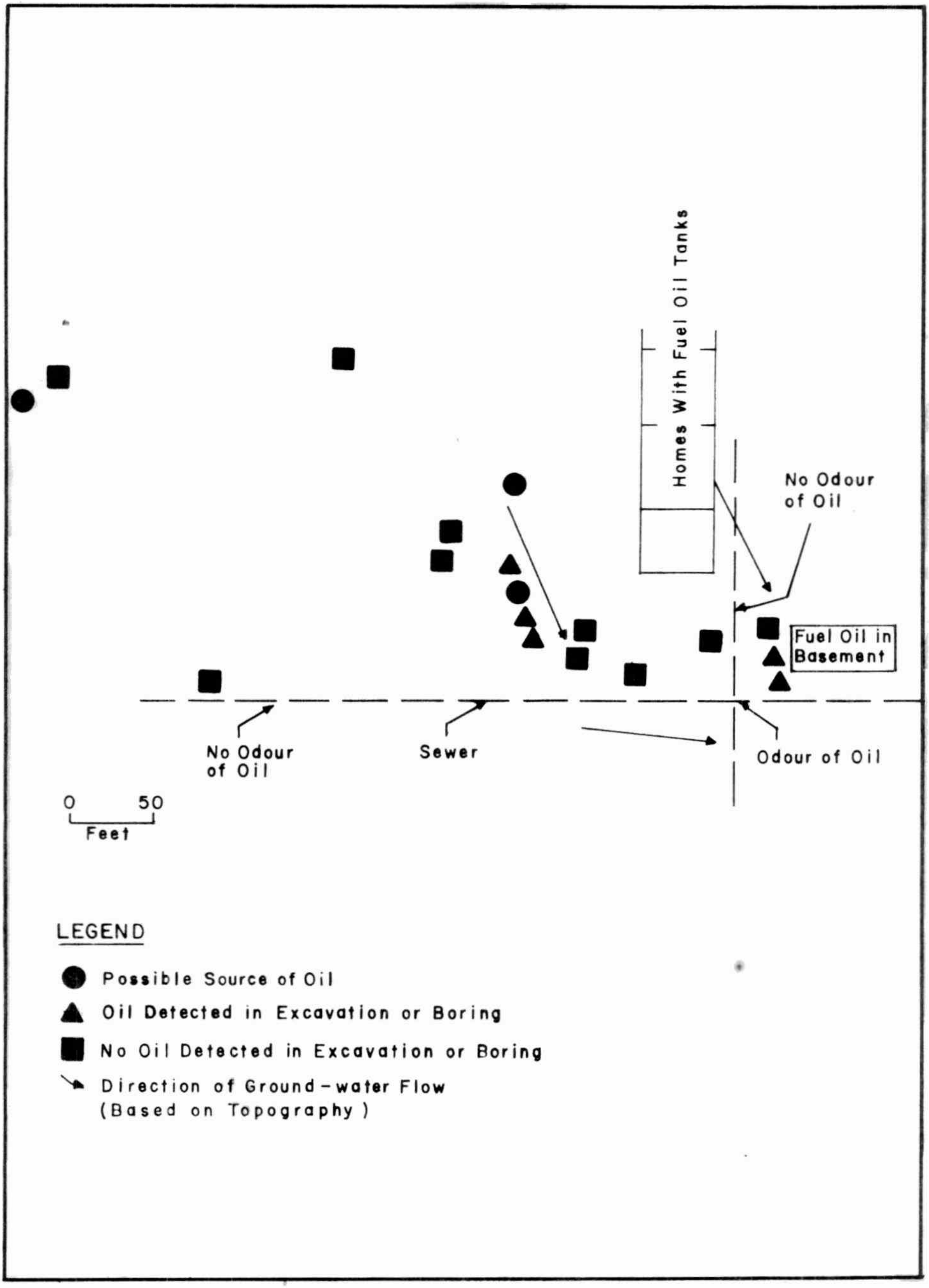


FIGURE 6: GROUND WATER CONTAMINATION CASE I

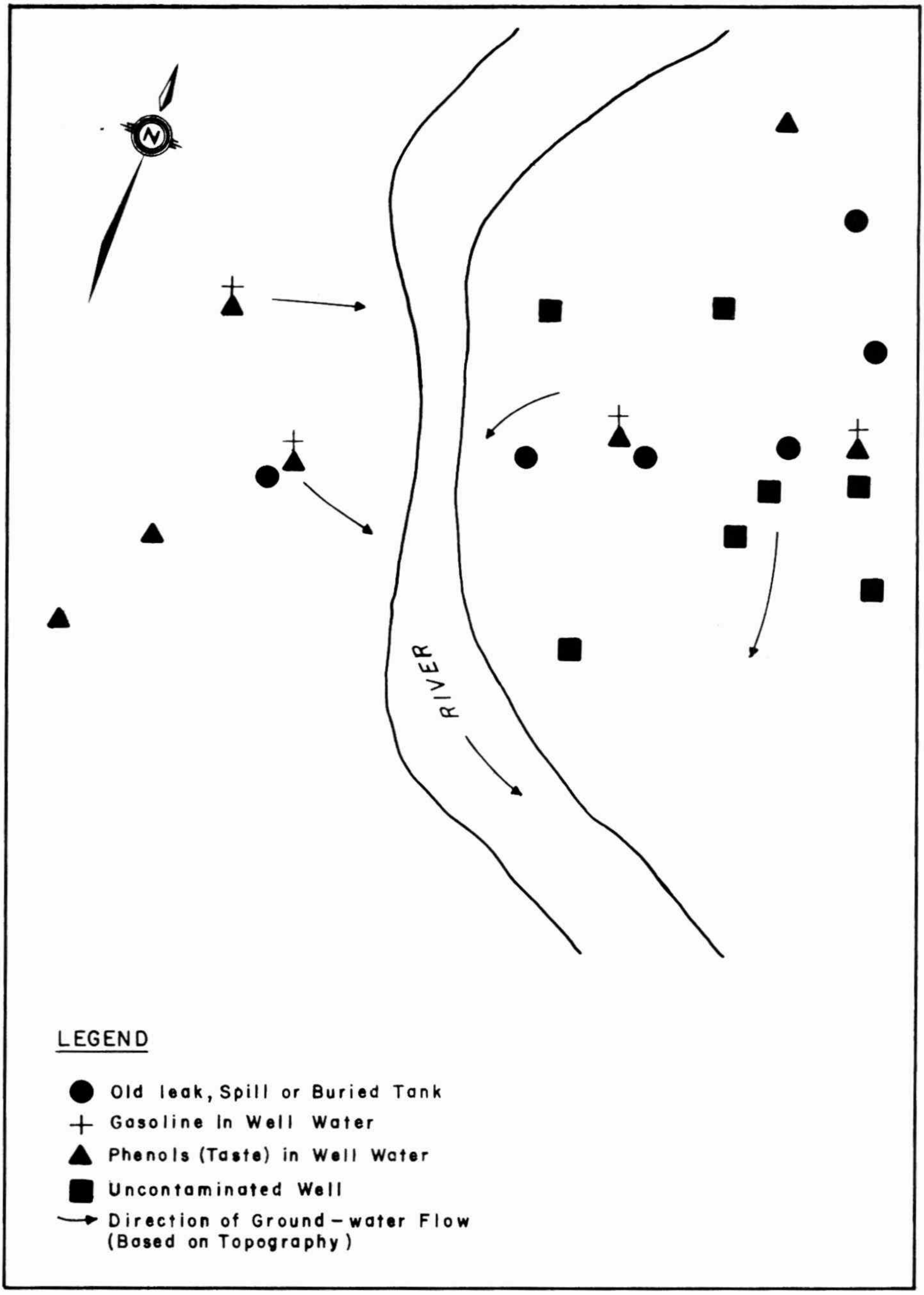


FIGURE 7: GROUND WATER CONTAMINATION, CASE 2

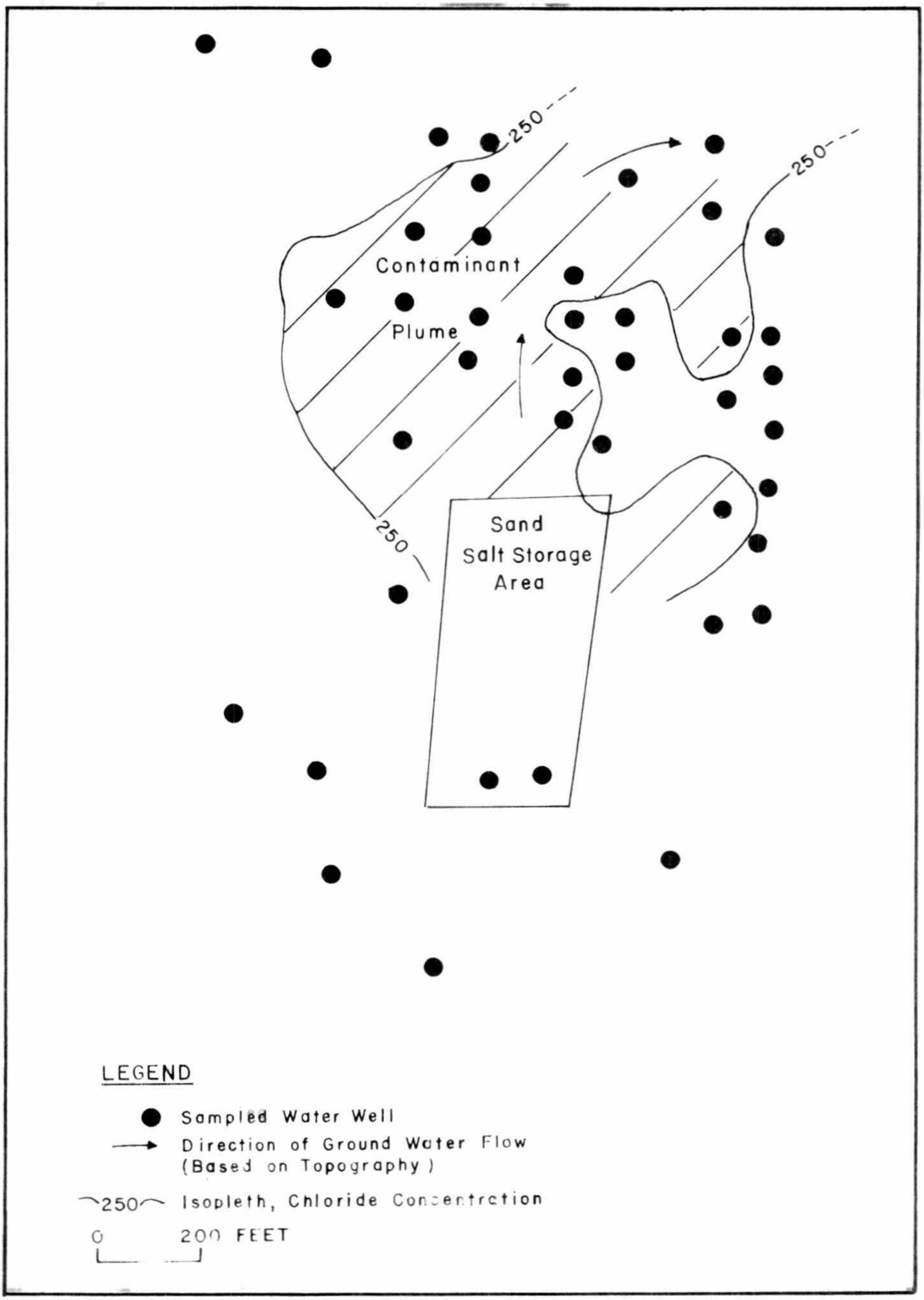


FIGURE 8 : GROUND WATER CONTAMINATION CASE 3

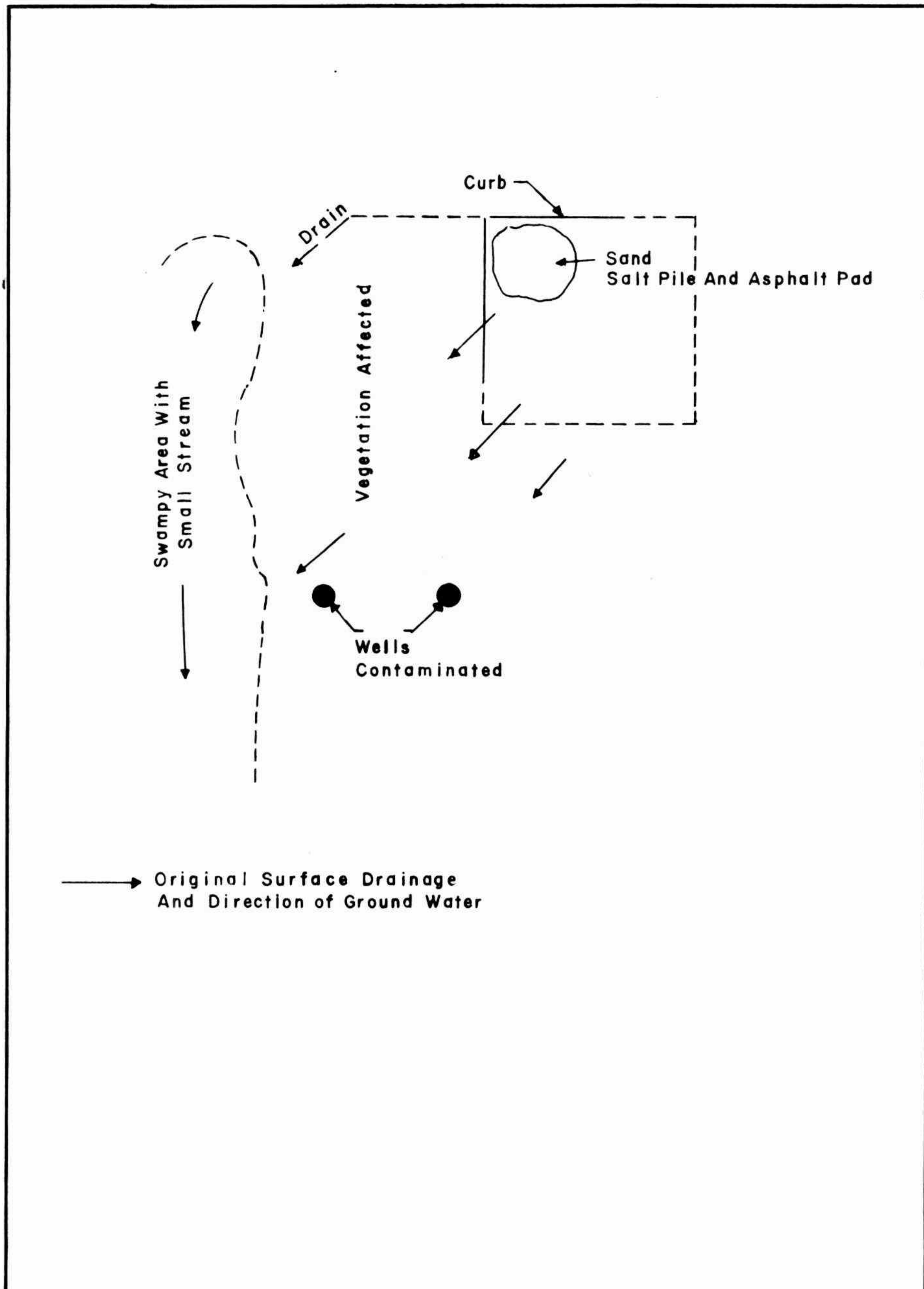


FIGURE 9 : GROUND WATER CONTAMINATION CASE 4

GEOTECHNICAL ASPECTS OF DISPOSAL AND CONTAINMENT OF LOW-LEVEL RADIOACTIVE WASTES

R. R. Turton

INTRODUCTION

It is paradoxical to consider that, whereas the prime object of waste or tailings disposal methods is to store SOLIDS and to confine them, our problems are largely caused by WATER. In Canada, this factor is compounded by our relatively humid climate.

Consequently, the main emphasis in geotechnical engineering design must be directed to control of possible water impoundment, to control of possible seepage, and to confinement of such seepage to designed local areas. The management of seepage is especially important with Uranium tailings since radioactive matter, such as Radium 226, is normally leached out of the waste due to the action of precipitation and groundwater.

Placing emphasis on seepage necessitates an appreciation, not just of the environment in regulatory terms, but of the local engineering geology; definition of the potential problems of the waste disposal site area; engineering design to accommodate and treat the potential problems and to allow for future abandonment; management and monitoring of construction in keeping with the design.

The principles noted above are examined by reference to the hazards and to concepts of the design and construction of tailings disposal areas.

HAZARDS OF URANIUM TAILINGS

A Uranium mining/milling operation has all of the common problems of waste disposal: confining solids as well as neutralizing acids, minimizing dissolved heavy metals and clarifying the liquid effluents. However, these aspects are compounded by the fact that the wastes, liquid and solid, are radioactive, albeit at a low level. The radioactivity in these wastes cannot be ignored since the phenomenon constitutes a hazard to health.

The Uranium isotope ^{238}U comprises more than 99 per cent of all natural Uranium deposits. This isotope stands at the beginning of a succession of different isotopes (nuclides). This succession develops in a definitive series by a process known as radioactive decay. The decay involves a spontaneous transformation of a given isotope into a new isotope with the

concurrent emission of electromagnetic radiation (gamma radiation) or charged particles (beta and alpha radiation). Although gamma radiation is deeply penetrating, alpha and beta particles have low penetrating power: alpha particles are stopped by a few centimetres of air or a sheet of paper; beta particles can penetrate a metre of air or a centimetre of water.

The first member, ^{238}U, is known as the parent, the intermediate members (heavy metal nuclides) are called daughters, and the final stable member, ^{206}Pb (Lead 206), is called the end product. A simplified radioactive decay series is shown on Table I. All of the transformations shown on the Table are occurring at one time. When the uranium ore reaches a given age, the daughters are formed at the same rate as they decay. This condition is known as secular equilibrium.

An approximate breakdown of the distribution of total radioactivity in a Uranium milling operation is given as follows:

Location	Fraction of Total Radioactivity (per cent)	Reference
Concentrate (product)	14	Merritt (1971)
Tailings Solids	50-86	
Liquid Effluent	< 1	Beverly (1968)
Radon Gas Generation	< 36	

The isotopes Radium 226 (^{226}Ra) and Thorium 230 (^{230}Th) are present in mill tailings and constitute the major radiological hazard in waste management operations. A summary of the distribution of Radium 226 and Thorium 230 within the mill for both acidic and alkaline leach processes is given in Table II.

It is generally accepted that more than 95 per cent of the Radium 226 in the ore passes through the mill and enters the tailings disposal area, essentially all of this Radium 226 being in solid form. Further, about 70 to 80 per cent of the Radium 226 will be contained in the fine grained portion of the tailings which are known as slimes. Radium is reportedly one of the most insoluble substances known; for example, the maximum solubility of Radium Sulphate is 0.02 parts/million; however, this maximum solubility is still equivalent to a

Table I. Simplified Uranium radioactive decay series
(After Dakers, 1976)

ISOTOPE	HISTORICAL NAME	HALF LIFE	RADIATION	REMARKS
^{238}U	Uranium I	4.5×10^{9} Years	α	
^{234}Th	Uranium X_1	24.1 Days	$\beta\gamma$	Major source of β emission in Uranium Ore
^{234}Pa	Uranium X_2	1.18 Min.	$\beta\gamma$	
^{234}U	Uranium II	2.5×10^{5} Years	$\alpha\gamma$	
^{230}Th	Ionium	7.6×10^{4} Years	α	Mill tailings
^{226}Ra	Radium	1620 Years	α	
^{222}Rn	Radon	3.82 Days	α	Gas
^{218}Po	Radium A	3.05 Min.	α	Internal α Hazard
^{214}Pb	Radium B	26.8 Min.	$\beta\gamma$	β and γ emissions in Uranium Ore
^{214}Bi	Radium C	19.7 Min.	$\beta\gamma$	
^{214}Po	Radium C^{1}	2.7×10^{-6} Min.	α	Internal α Hazard
^{210}Pb	Radium D	22.0 Years	$\beta\gamma$	
^{210}Bi	Radium E	5.0 Days	β	
^{210}Po	Radium F	138.4 Days	α	
^{206}Pb	Radium G	Stable		

Table II. Distribution of isotopes (^{226}Ra, ^{230}Th) in mill processe
(After Merritt, 1971)

ISOTOPE/LOCATION DISSOLVED	AMOUNT DISSOLVED (per cent)	
	Acidic Leach	Alkaline Leach
Radium 226/leaching process	0.25 to 0.7	1.5 to 3
Thorium 230/leaching process	< 50	0
Radium 226/ion exchange	0.1	Not Applicable
Thorium 230/ion exchange	< 5	Not Applicable

radiological concentration of 15×10^6 pCi*/litre in the liquid effluent, which is markedly higher than the present Ontario guideline of 3 pCi/litre. However, the measured concentration of Radium in existing tailings ponds has been found to be much less than the maximum values possible. The results of measurements from 15 tailings ponds in the U.S.A. give an average value Radium 226 concentration of 350 pCi/litre, the data ranging from 10 to 2,100 pCi/litre** (Merritt, 1971). As pointed out by Yourt (1966), the Radium will not dissolve unless it is in agitated contact with large quantities of water, the ideal proportion being 1,000 parts of water to 1 part of fines containing Radium. From this, it is evident that essentially all of the Radium remains in the tailings disposal area and undergoes the transformation or decay to the next radio-nuclide in the series: ^{222}Rn, or Radon, which is an inert gas. It can be seen on Table I that Radon heads a group of radio-nuclides which in turn decay over a relatively brief time and, as such, are relatively hazardous. Dakers (1976) writes - "the rate of Radon emanation from dry tailings is primarily dependent on the Radium concentration and on the fraction of Radon that can escape from the solids and is free to diffuse. It has been found experimentally that 20 to 25 per cent of the Radon produced is released from the tailings particles and that effectively only the Radon produced in the first meter depth of tailings will diffuse to the atmosphere." It is further understood that Radon gas produced in submerged tailings will be buoyed up to the pond surface and will escape to the atmosphere.

In acid leach plants the Radium which is dissolved in the liquid effluent is commonly treated with a barium salt, barium chloride being one of the most effective. The product of this treatment, a radium-barium sulphate co-precipitate, is normally deposited in a settling pond(s) before release into the environment. In alkaline leach mills the Radium can be partially removed from the liquid effluent by the addition of barite.

GEOTECHNICAL PROPERTIES OF TAILINGS

Uranium tailings from the standpoint of geotechnical properties and apart from the special hazardous characteristics discussed above are similar to tailings from other milling operations. Their principal properties are reviewed below.

Gradation: Grain size distribution curves of tailings produced from four principal types of Uranium deposit are plotted on Fig. 1 together with the gradation characteristics of tailings produced

*pCi = 1×10^{-12} Ci

**Measurements at the tailings ponds for active mines near Elliot Lake, Ontario, gave values ranging from 300 to 1,000 pCi/litre.

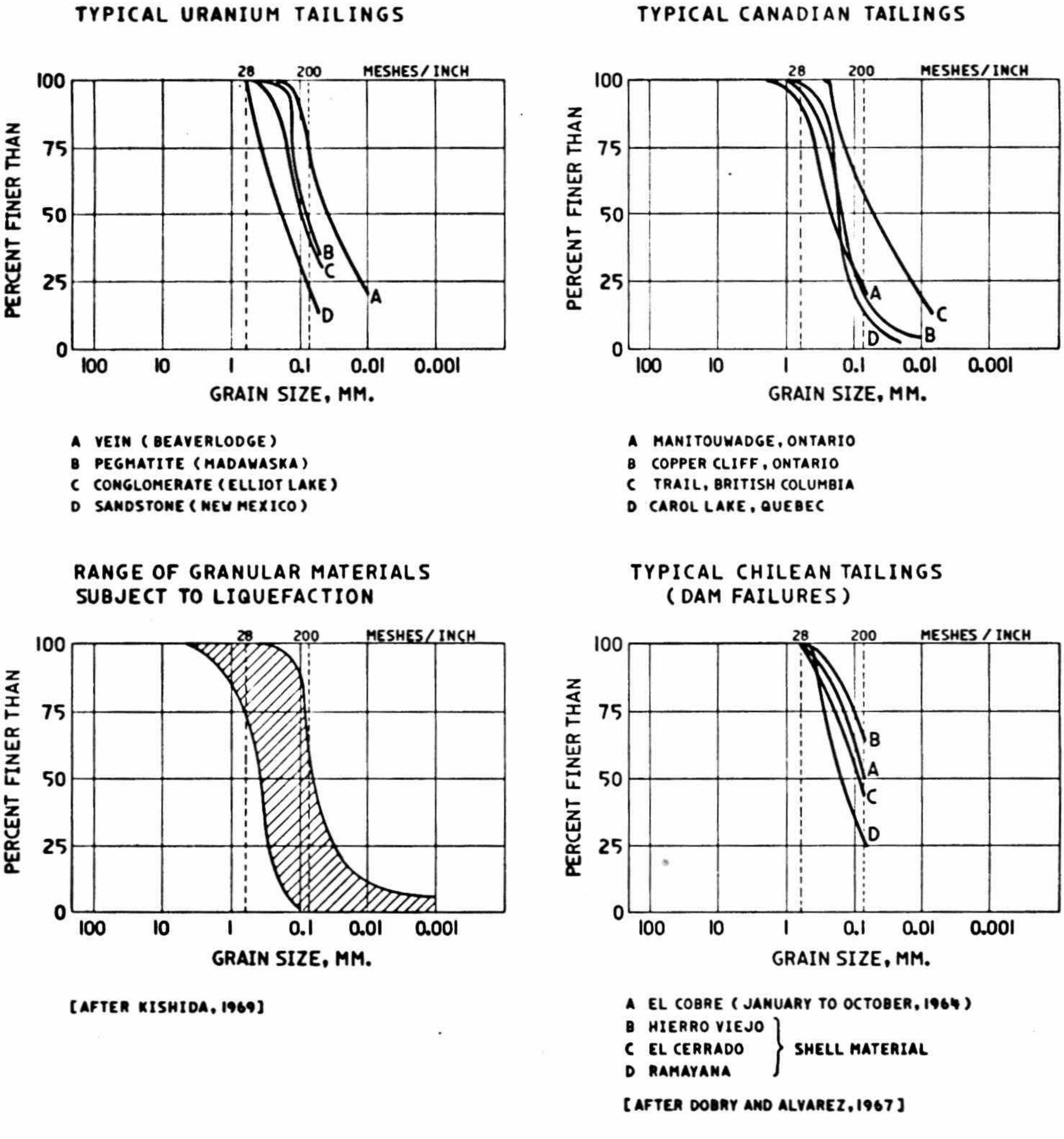


FIG. 1 GRADATION OF TAILINGS

by typical metal mines. Despite the possible variations in host rock or milling processes, the 'envelopes' occupied by these two groups of curves are similar and remarkably consistent in gradation. The figure also illustrates the gradation of certain tailings deposits which have failed by liquefaction due to seismic shock. It should be noted that the majority of tailings deposits are of critical gradation with respect to liquefaction.

Permeability: The coefficient of permeability, k, for coarse grained granular materials has been found experimentally to vary directly with the square of the ten per cent size, D_{10}. This parameter is defined as the particle size, for a given soil sample, for which 10 per cent of the sample is finer grained. The results of permeability tests carried out on tailings indicate that this relationship can be extended to cover these relatively fine grained granular materials (Ref. Fig. 2). The data on the figure also illustrate that many tailings are not impervious; most of the results fall in the permeability range from 1×10^{-4} to 1×10^{-2} cm/sec.

Strength Properties: When tailings are deposited in a tailings pond, i.e. in a submerged condition, the undrained shear strength of the finer portion of the tailings (slimes) is very low, the material having the properties of a viscous fluid. However, with the accumulation of additional tailings in the pond, the strength of the buried tailings increases. Similar to many natural cohesive deposits, the increase in shear strength is approximately linear with respect to increasing depth below the tailings surface. The results of in situ undrained shear strength tests carried out on tailings slimes are given on Fig. 3. It should be noted that exposure of slimes to the air results in an appreciable increase in undrained shear strength due to desiccation. The results of strength tests carried out in desiccated slimes in South Africa are also presented on Fig. 3.

In contrast to the low undrained strength of tailings when initially deposited, the "drained" shear strength is high, largely because of the angular shape of the individual grains, the competent nature of the host rock material and the relatively high permeability. The measure of drained strength, known as the angle of internal friction, ϕ', generally ranges between 32° and 39° for tailings (Wahler et al, 1974; Guerra, 1973; Golder Associates, 1974; Klohn and Maartman, 1973).

The greater problem which relates to the low undrained shear strength of loosely deposited tailings arises from the possibility of liquefaction due to shock or dynamic loading. This is regrettably common (see Fig. 1) where the tailings are deposited loosely and not adequately compacted or drained.

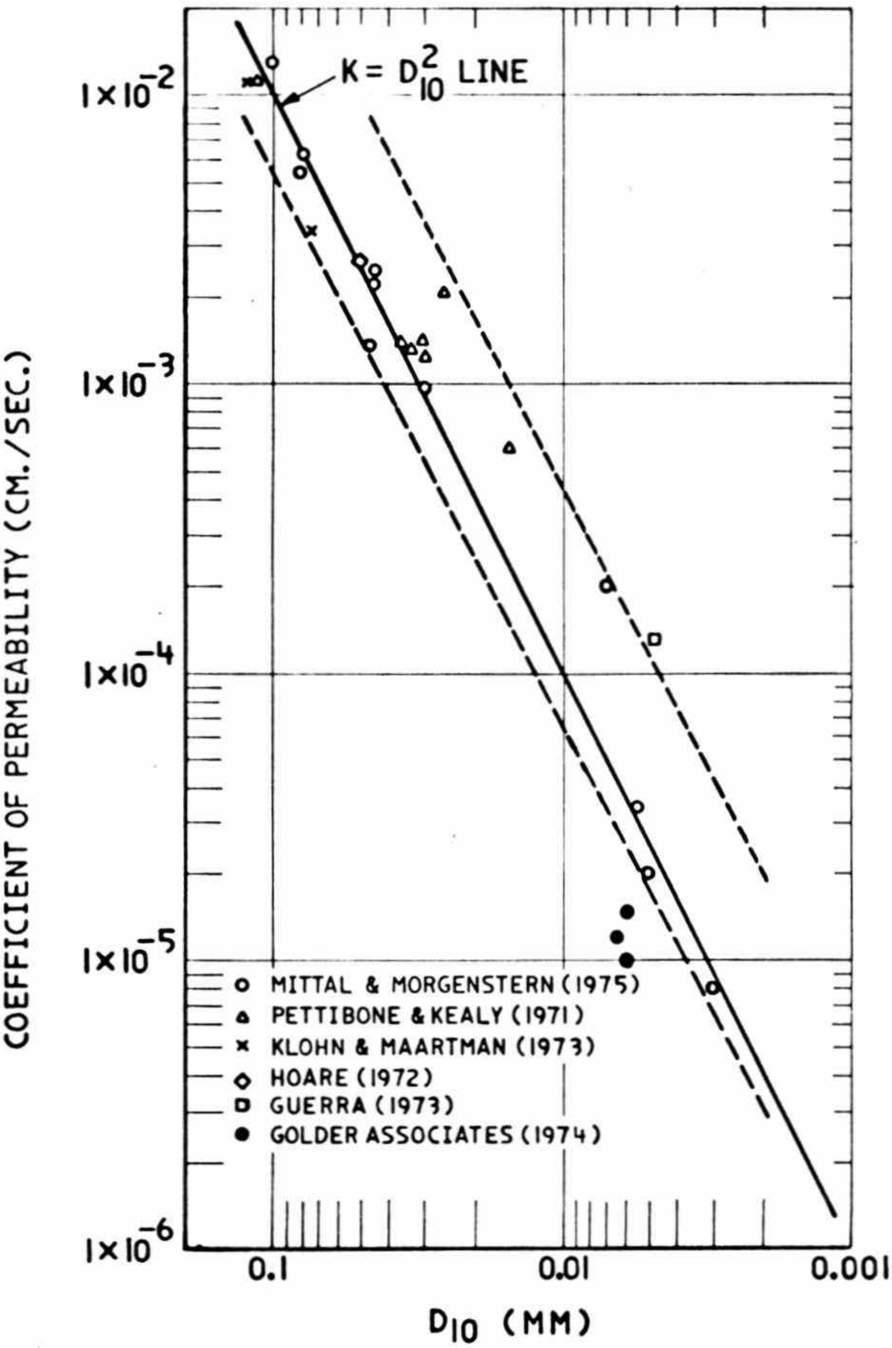


FIG. 2 PERMEABILITY OF TAILINGS

VS D_{10} SIZE

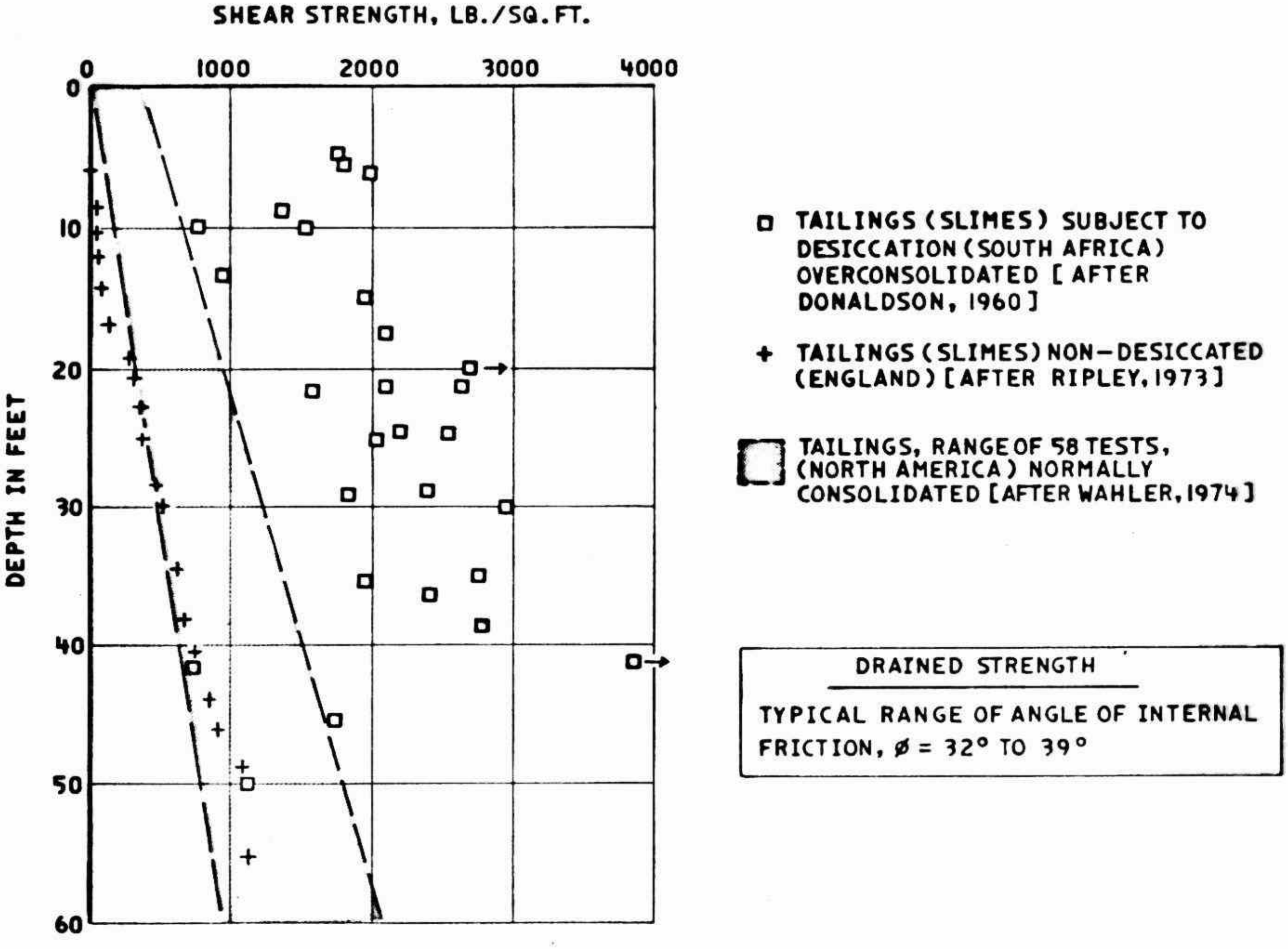


FIG. 3 TYPICAL STRENGTH PROPERTIES OF TAILINGS, IN SITU

Susceptibility to Erosion: Because tailings are relatively fine grained granular materials they are easily eroded by water. Due to the radioactive nature of Uranium tailings, of equal importance is the erodability of Uranium tailings by wind action. As with water flowing over a rough surface, wind also exhibits a velocity profile with respect to ground surface. In fact, there is a very thin layer at ground surface in which the velocity is zero, the thickness of the layer depending on the roughness of the bed and generally about 1/30th of the particle diameter for granular materials such as tailings. Above this layer the wind velocity increases as illustrated in Fig. 4. As the wind velocity increases, the loose particles on the surface of the tailings will be subject to increasing stress and will eventually begin to move. The initial velocity at which particle movement begins was referred to as the fluid threshold by Bagnold, 1941. As is shown on Fig. 4, the fluid threshold varies with particle size. Further, there appears to be an 'optimum' size, about 0.1 mm, which is particularly susceptible to wind erosion. (It should be noted that this size is close to the median size for most tailings.) For particles larger than 0.1 mm the relationship with respect to wind velocity is readily understandable. The paradoxical increase in threshold velocity for fine grained materials is related to weak interparticle cementation bonds, greater moisture retention, and to lower values of surface roughness.

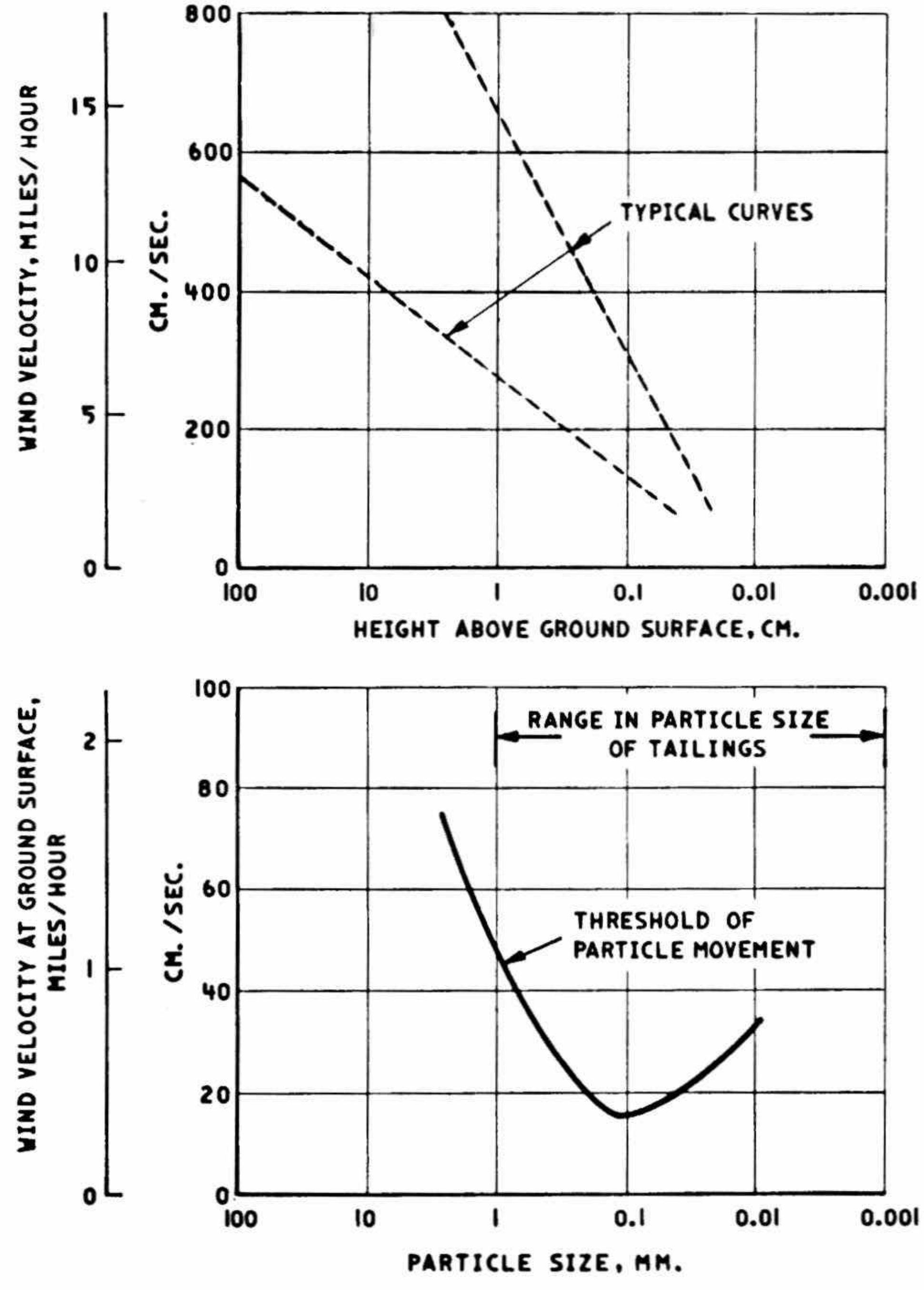
SIGNIFICANT POINTS OF TAILINGS DAM DESIGN

The design of tailings dams is controlled, as in earth fill dams, by the strength of the fill material when placed, the character of the foundations and seepage control measures.

It should be stressed that, because of potential hazards due to either random losses of radioactive slimes or of the supernatant liquid, the control of stability of the dykes or dams and of seepage is possibly even more important in waste disposal areas than in simple water retention reservoirs.

The first key to the prevention of losses is an adequate geological assessment of the disposal area(s). Engineering design must be tailored to the specific geology of each site and take into account the availability of local materials. It is essential that an analysis of the hydrological characteristics of the tailings disposal area be carried out as a safeguard against failure due to overtaxing of the spillway/decant system.

A summary of the major common problems with tailings dams is given on Table III together with discussions of remedial measures or steps to be taken in design.



[AFTER BAGNOLD, 1941]

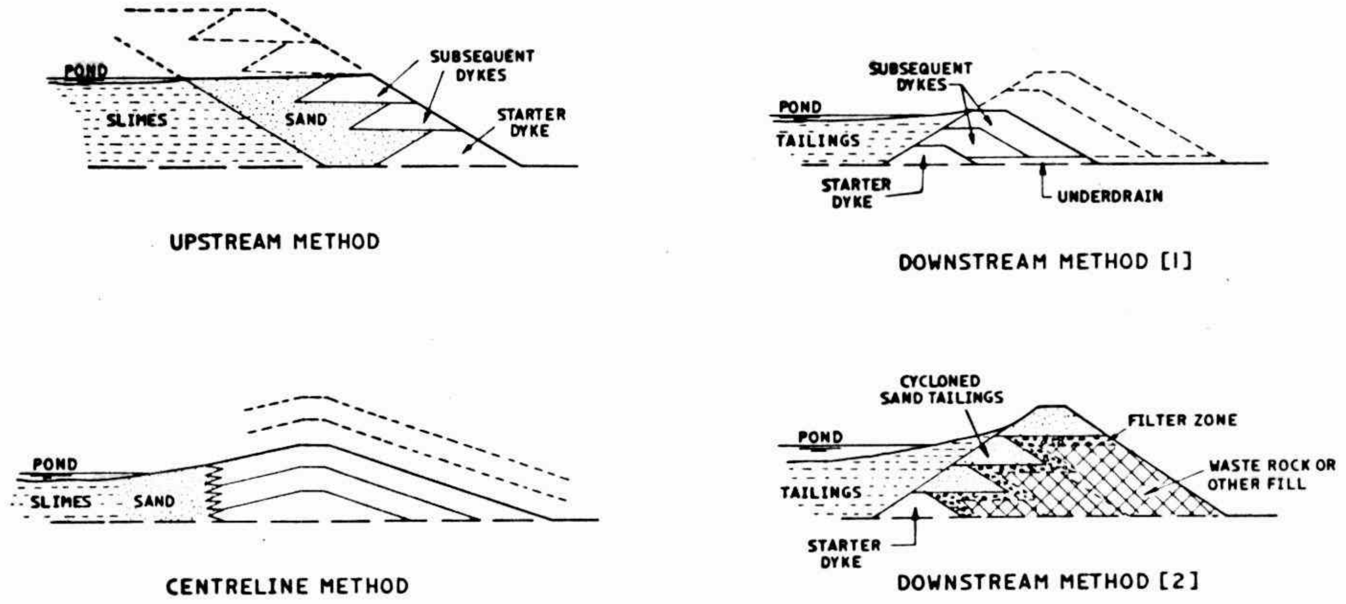
FIG.4 WIND EROSION OF TAILINGS

Methods of Construction/Design: Three common methods of tailings dam construction/design are illustrated on Fig. 5. With each method it is possible to produce an embankment which will safely contain the tailings solids provided good compaction is obtained and drainage control measures provided; however, the downstream types of construction have the advantage that they allow us to produce the best fit to an idealized earth dam section, as illustrated on Fig. 6. The idealized section is desirable because it provides the best balance between impervious zones and drainage features. Such a section, if followed, will result in small or negligible seepage losses which can be controlled. The figure also gives a first approximation to the possible slope angles for a range of common fill materials.

Seepage Problems: The inherent mistake in constructing an earth dam as a fully homogeneous section is illustrated on Fig. 7. This error is common for dams which are not designed. As shown on the figure, the addition of downstream berms of material similar to that within the body of the dam does not wholly remedy the problem. The proper remedial measure involves the design and construction of effective drains and filters as shown on Fig. 8. These zones are sufficiently coarse to be free-draining yet are sufficiently fine and so graded to prevent migration of fine particles from the body of the dam due to seepage forces. The problem of seepage emergence can be obviated in the first instance by proper design of an internal drainage system. Two examples of such systems are illustrated schematically on Fig. 9.

Of equal importance are seepage losses associated with the dam foundations. Although it may not be possible to prevent seepage in all cases, it is important that the seepage be contained and positively collected for chemical treatment prior to its release into the environment or for recycling. A summary of methods for controlling foundation seepage is given on Table IV.

Control of Pond Levels: The balance of 'free' water in a tailings and slimes pond is of major importance. All precipitation runoff, snow melt and tailings effluent must be channeled from the pond to avoid incurring erosional damage to the tailings dams and possible loss of tailings solids. In certain cases, as illustrated on Fig. 10, the tailings disposal area is provided with an emergency spillway to channel the maximum probable flood past the tailings dam. During such periods of emergency the practice of chemically treating the effluent must be abandoned in favour of protecting the tailings dam itself.



[AFTER DEPARTMENT OF ENERGY, MINES AND RESOURCES, OTTAWA, 1972]

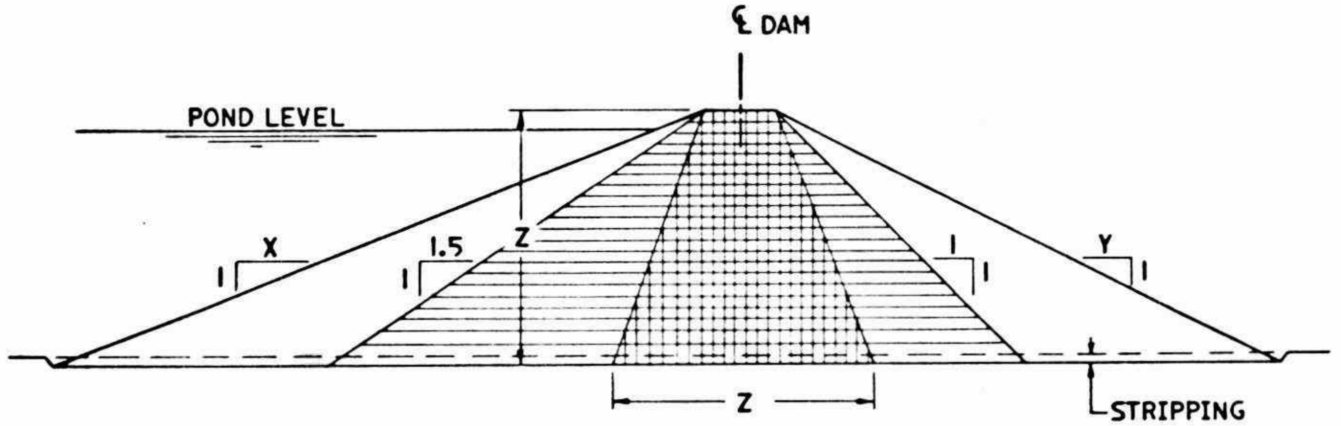
FIG. 5 METHODS OF DYKE CONSTRUCTION

APPROXIMATE SLOPE GUIDELINES [AFTER MERRITT, 1971]

EMBANKMENT MATERIALS	X	Y
COARSE TAILINGS	2.5	2
HOMOGENEOUS SAND LOESS	3	3
HOMOGENEOUS SILTY CLAY	4	3
SAND AND GRAVEL WITH CLAYEY CORE	3	2

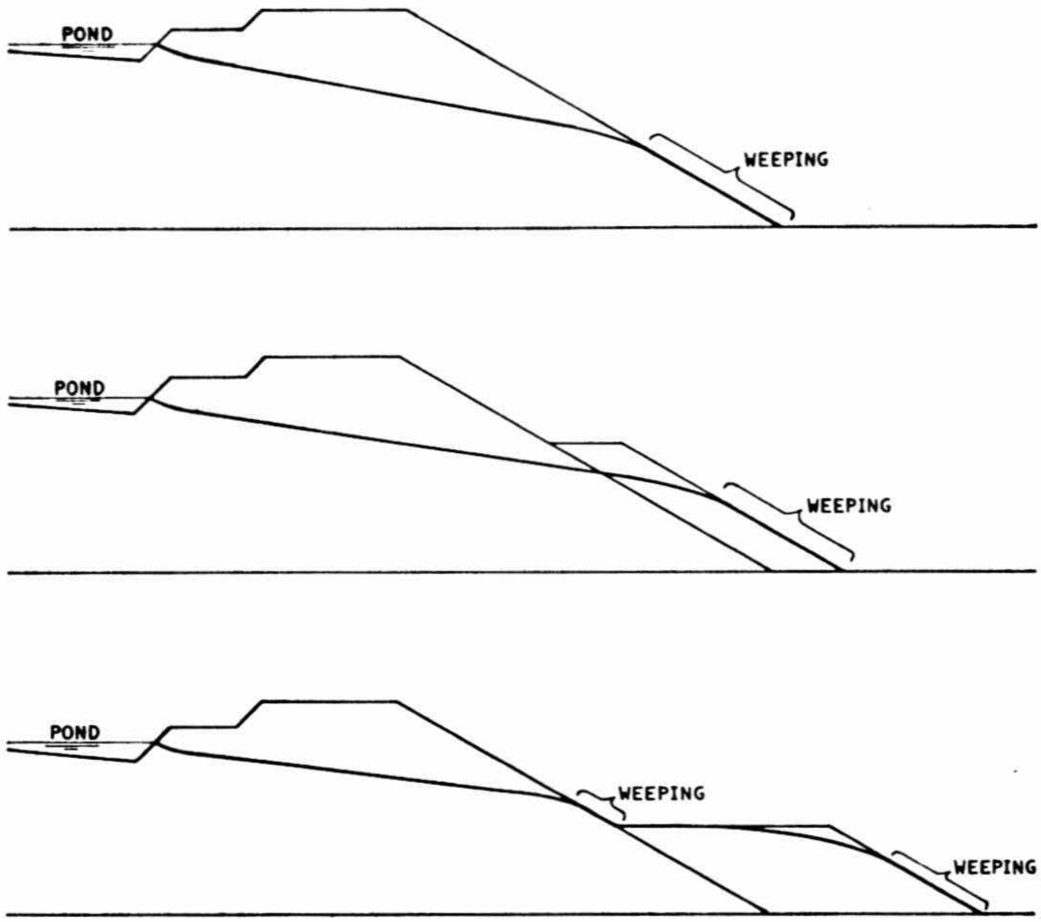
MINIMUM CORE FOR DAM ON PERVIOUS FOUNDATION, NO POSITIVE CUTOFF TRENCH

MINIMUM CORE FOR DAM ON IMPERVIOUS FOUNDATION OR PERVIOUS FOUNDATION WITH POSITIVE CUTOFF



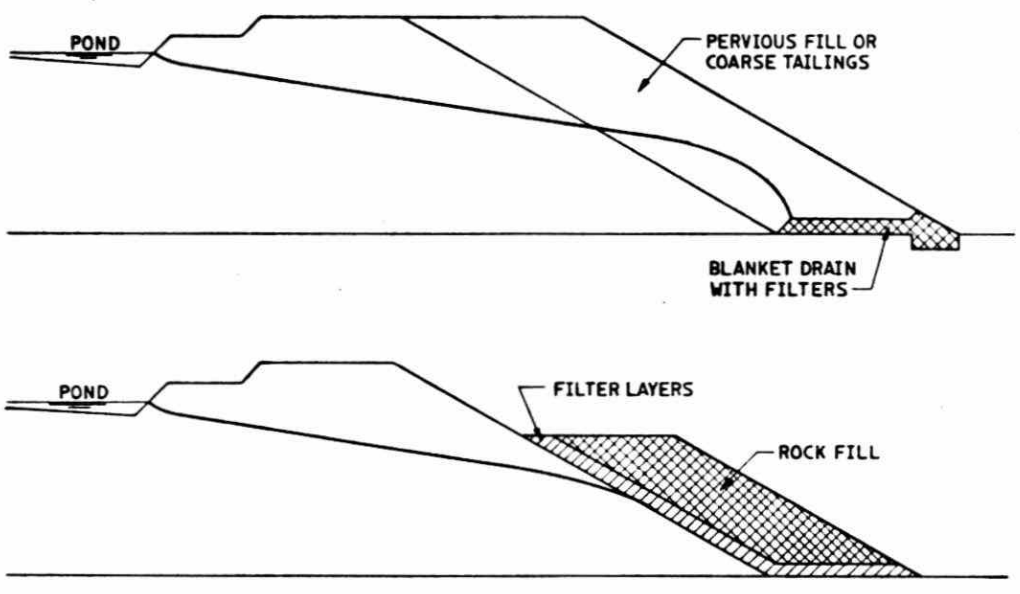
[AFTER UNITED STATES DEPARTMENT OF THE INTERIOR, 1960]

FIG. 6 IDEALIZED DAM / DYKE SECTION



[AFTER DONALDSON, 1960]

FIG. 7 UNCONTROLLED SEEPAGE THROUGH DYKES



[AFTER DONALDSON, 1960]

FIG. 8 REMEDIAL MEASURES TO CONTROL SEEPAGE EMERGENCE

Table III. Geotechnical problems with tailings dams

Problem	Cause(s)	Possible Remedial Measures	Reference
SEEPAGE RELATED			
a) Internal erosion - piping	Preferential seepage path(s) and resulting high exit gradient of seepage. Caused by non uniform compaction, defect in foundation, water soluble materials, burrowing animals, differential settlement cracks, lack of seepage controls around decant tunnels and the like. Lack of, or improperly graded filters.	Cover leak with select filter material which will prevent further loss of ground.	Fucik (1952)
		Cut off the "pipe" (e.g. sheet piling or slurry wall).	Wahler & Associates (1973)
b) Overtopping	Blockage of decant system and/or emergency spillway.	Clear blockage to decant system or spillway.	Ripley (1973)
	Occurrence of storm larger than design storm.	Excavate temporary spillway at abutment.	
c) Collapse of decant system	Deterioration of conduit. Lack of, or improper design. Poor construction practice.	Replacement of system may be required.	Ripley (1973)
d) Erosion of downstream shell	Lack of proper rip-rap.	Provide rip-rap.	Sherard (1953)
	Poor grading which leads to concentration of precipitation runoff.	Grade to minimize concentration.	
	Lack of storm runoff channels; e.g. at abutments.	Provide properly lined storm runoff ditches.	
e) Erosion of upstream shell	Lack of proper rip-rap.	Provide proper rip-rap.	Jewell (1945)
	Unanticipated floating debris in reservoir.		
	Wave action which exceeds design wave height.		
FAILURE OF EMBANKMENT MATERIAL	Weak construction materials.		
	Excessively steep overall downstream slope.	Flatten downstream slope.	Salas (1969)
	Buildup of pore pressures during or after construction.	Slow fill placement rate to allow for dissipation of pore pressures.	Ripley (1973)
	Surficial erosion of downstream toe	Repair erosion features.	
a) Liquefaction	Relative density, D_r < 70 per cent	None	Dobry and Alvarez (1967)
	Median grain size D_{50} < 2 mm		
	Saturation.		Seed and Idriss (1971)
	Seismic disturbance; e.g. blasting, earthquake, slope failure, ground acceleration > 0.13 g		
FOUNDATION FAILURE	Presence of relatively soft (weak) cohesive subsoil in dam foundation.	Rebuild downstream slope with flatter slope or provide stability berm.	Eschario (1961) Salas (1969)

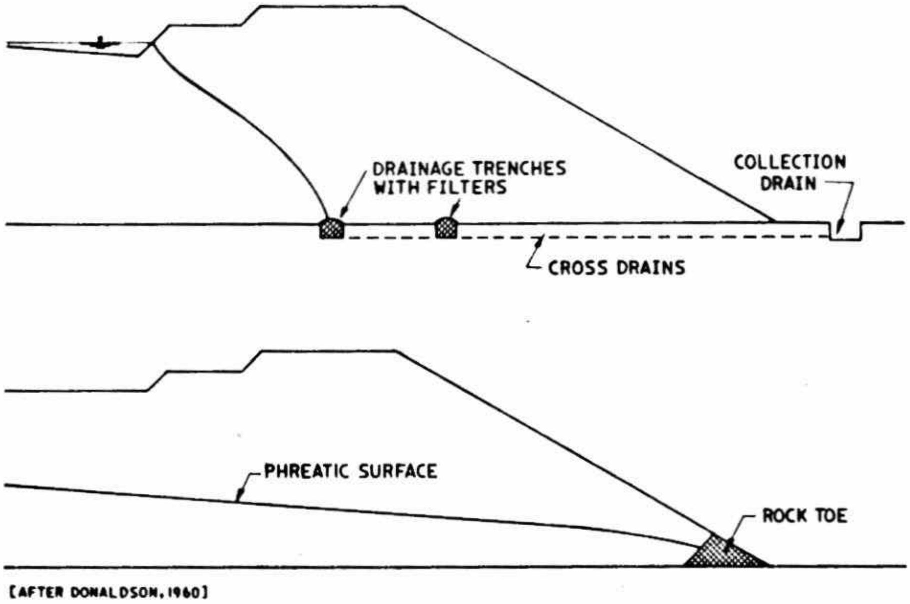
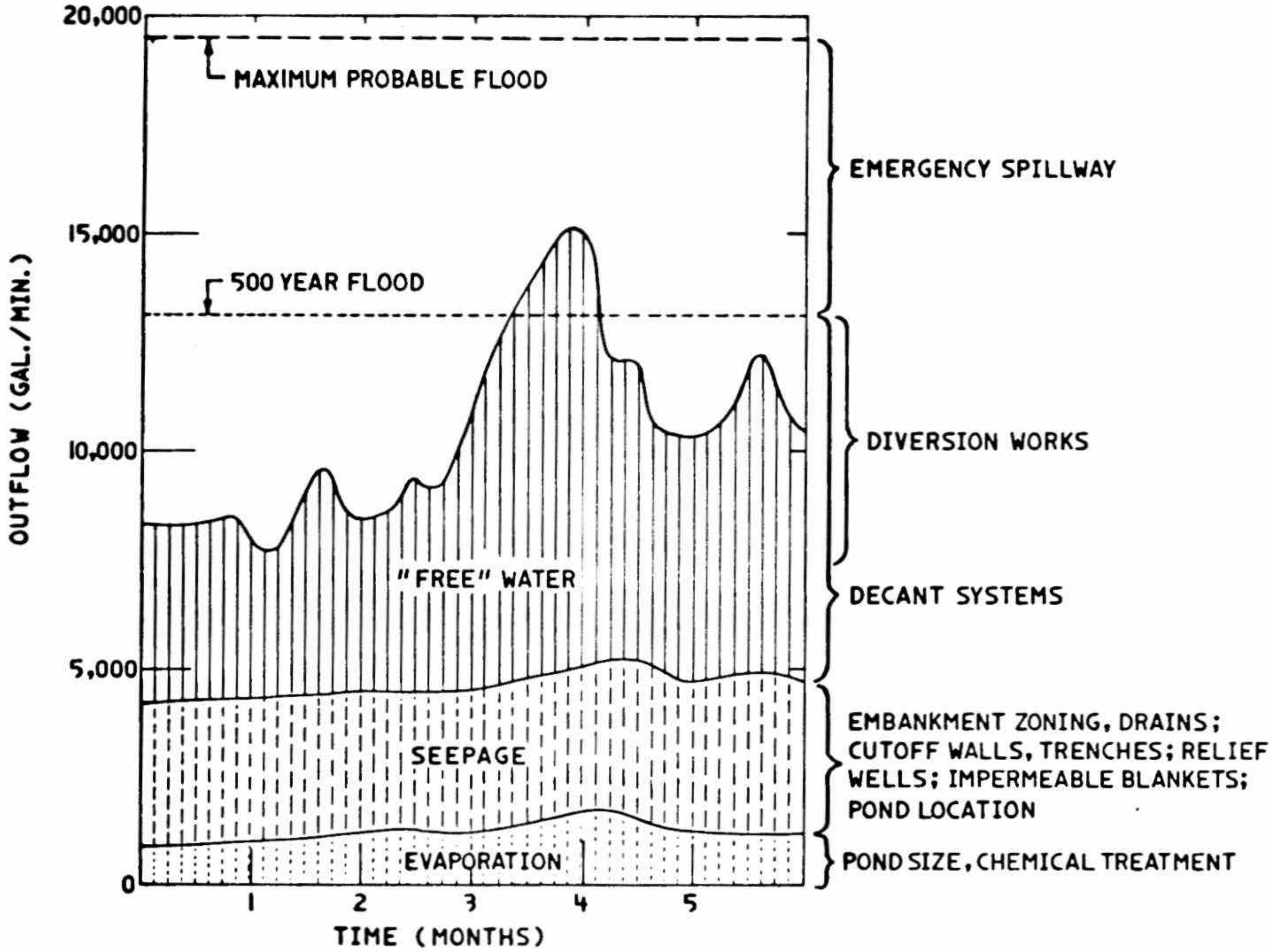


FIG. 9 CONTROLLED SEEPAGE THROUGH DYKES



[AFTER SWAISGOOD AND TOLAND, 1973]

FIG. 10 WATER OR LIQUID BALANCE IN TAILINGS PONDS

Table IV. Control of seepage through foundation(s)

Foundation Conditions	Magnitude of Seepage Through Foundation	Possible Methods of Minimizing Foundation Seepage	Notes
Impervious Rock or Soil	Minimal	None required.	
Pervious Rock Overlying Impervious Rock	Minimal to substantial (depending on character and degree of fracturing).	Excavation of rock and construction of cutoff.	Practical if pervious rock is less than 30 ft. thick and rock is rippable.
		Grout curtain.	Practical k $> 10^{-3}$ cm/sec. and if rock is not rippable.
Pervious Rock or Soil $>$30 ft. thick	Substantial	Grout curtain (rock).	Max. depth 200 ft. (see 'k' above).
		Concrete diaphragm - slurry construction (soft rock or soil).	Max. depth 250 ft.
		Slurry wall - no concrete (soft rock or soil).	Max. depth 50 ft.
			Indirect methods - complete cutoff cannot be assured.
Pervious Rock or Soil $>$200 ft. thick	Substantial	Impervious upstream blanket.	Thickness of soil blanket depends on permeability of blanket material and underlying pervious zone.
			Synthetic membrane requires bedding to prevent puncture.
Impervious Soil $<$10 ft. thick Overlying Pervious Soil or Rock	Minimal to appreciable	None required if impervious soil acts as effective barrier; otherwise see above.	

During the operating period of the mill, most of the surplus water from the tailings disposal area will pass through some form of decant system. These systems fall into two general categories: fixed and moveable types. The fixed types consist of a buried horizontal outlet pipe, which carries the effluent beneath the dam to the downstream toe, and an inlet device which can consist of a tower or a structure which is founded on the side-wall of the tailings pond (Ref. Figs. 11(a) and (b), respectively). The moveable types consist of inlets which float on the surface of the pond or are maintained on an inclined track which runs up the side-wall of the pond (Ref. Figs. 11(c) to (e), inclusive). A comparison of decant systems is presented on Table V together with a discussion of their advantages and disadvantages. The choice of a specific system depends on the needs of each waste disposal area.

To illustrate some of the design principles described in earlier sections of this paper, two tailings dams at the Denison Mines Limited property near Elliot Lake are discussed.

CASE HISTORY - DESCRIPTION OF DENISON TAILINGS DISPOSAL AREA

The area selected for disposal of mill tailings at Denison Mines Limited near Elliot Lake, Ontario, consists of a valley occupied by what is known as Long Lake. This valley is characterized by a nearly continuous "rim" of surrounding relatively impervious bedrock. A plan of the disposal area is given on Fig. 12. It is estimated that the total area covered by tailings at this elevation will amount to about 250 hectares (600 acres). The capacity of the storage area (to elev. 9160 ft., Local datum) is estimated to be about 70 million tons (dry weight basis). The average depth of tailings within the disposal area will be about 20 m (65 ft.). It is expected that the Long Lake basin will serve to contain the entire tailings production of the mine.

The disposal procedure involves discharging the tailings in slurry form via pipeline and/or open channel flow into the east end of the Long Lake basin (for location see Fig. 12). The pH of the slurry, on discharge from the mill, is chemically adjusted to be slightly basic (about 9). In flowing approximately 1 mile to the outlet of the basin, the solids drop out of the slurry and are deposited on the floor of the valley. The supernatant liquid is decanted off at the west end of the valley and is automatically treated with a 20 per cent barium chloride solution which co-precipitates Radium 226 along with other heavy metals. The precipitates are contained in a settling pond known as Stollery Lake, which is located immediately downstream of the treatment facility.

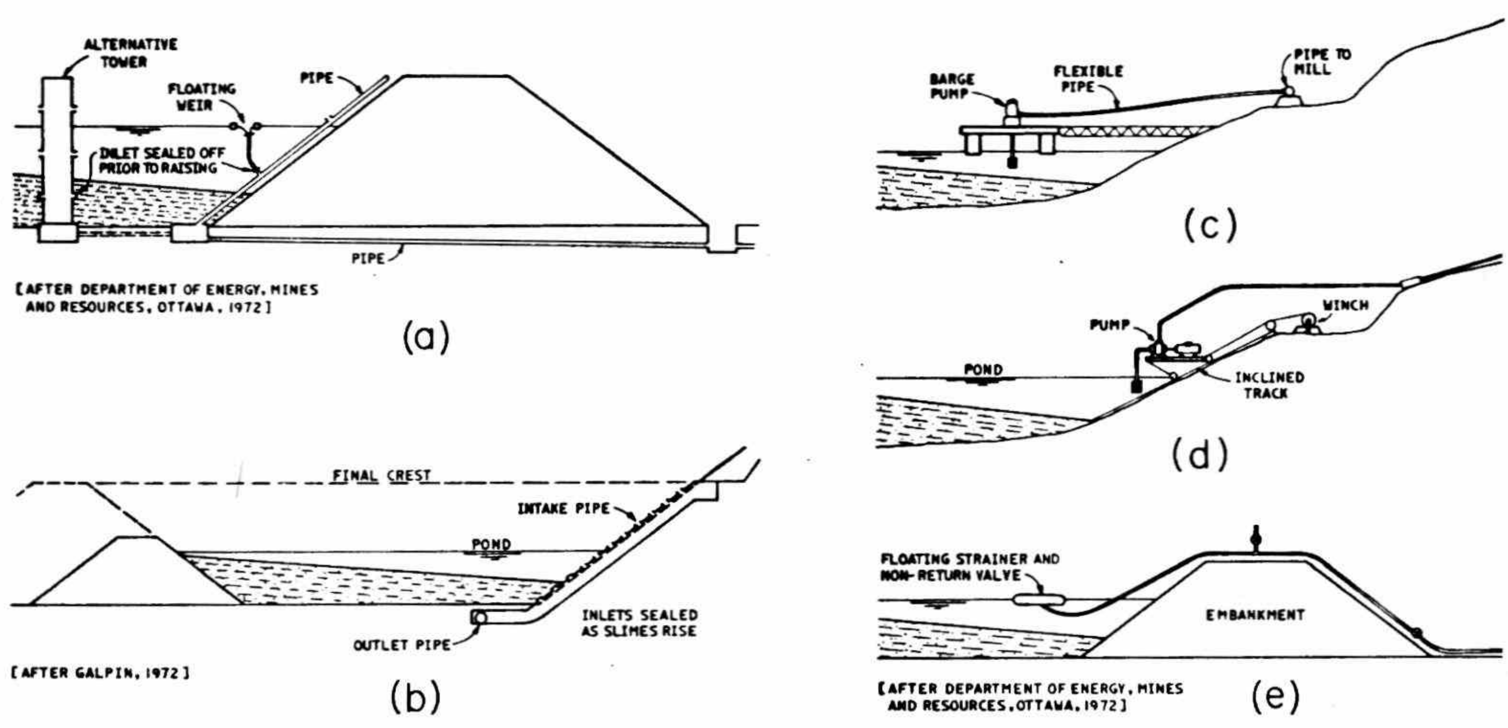


FIG. 11 DECANT SYSTEMS FOR POND LEVEL CONTROL

Table V. Control of pond levels - comparisons of decant systems (After Galpin, 1972)

Feature	Floating Pump or Syphon System	Buried Decant Line System*
Design and Construction	Pontoon, pump, and return line must be resistant to corrosion. Once barge and pump are installed the only construction requirements are extensions to the return line.	Design and construction is simple. May be carried out in a single operation or in multiple stages.
Operating Requirements	Pump operator required full time in addition to other operators.	Intermittent checking all that is required.
Flexibility	Requires relocation with changing position of free-water pond. Lack of maneuverability would cause problems in early stages when position of pond varies widely. Gives a little more control over quality of return liquor.	No relocation required. Permanent pump installation downstream of embankment.
Maintenance	Pump and barge require considerable maintenance, especially during freezing weather.	Low maintenance requirements for downstream pump.
Potential for Malfunction	Floating pump is more prone to breakdown and damage than fixed pump, due to blockage by flotsam. Power outage or pump breakdown could lead to overtopping.	Requires firm foundation. Settlement of embankment could cause rupture of line. Blockage or rupture of buried line is irreparable. Possibility of "piping" failure along the line in outer portion of embankment.
Flood Control	Removal of floodwaters from storage is limited by the capacity of the pump.	Discharge capacity of pipe increases with corresponding increase in head due to flood conditions.
Drainage of Structure After Abandonment	After termination of discharge operations, new drainage scheme required to handle surface runoff.	Decant system would provide permanent drainage of storage, facilitating reclamation.

*Note: Such systems also include the side-wall decant system shown in Figure 11(b).

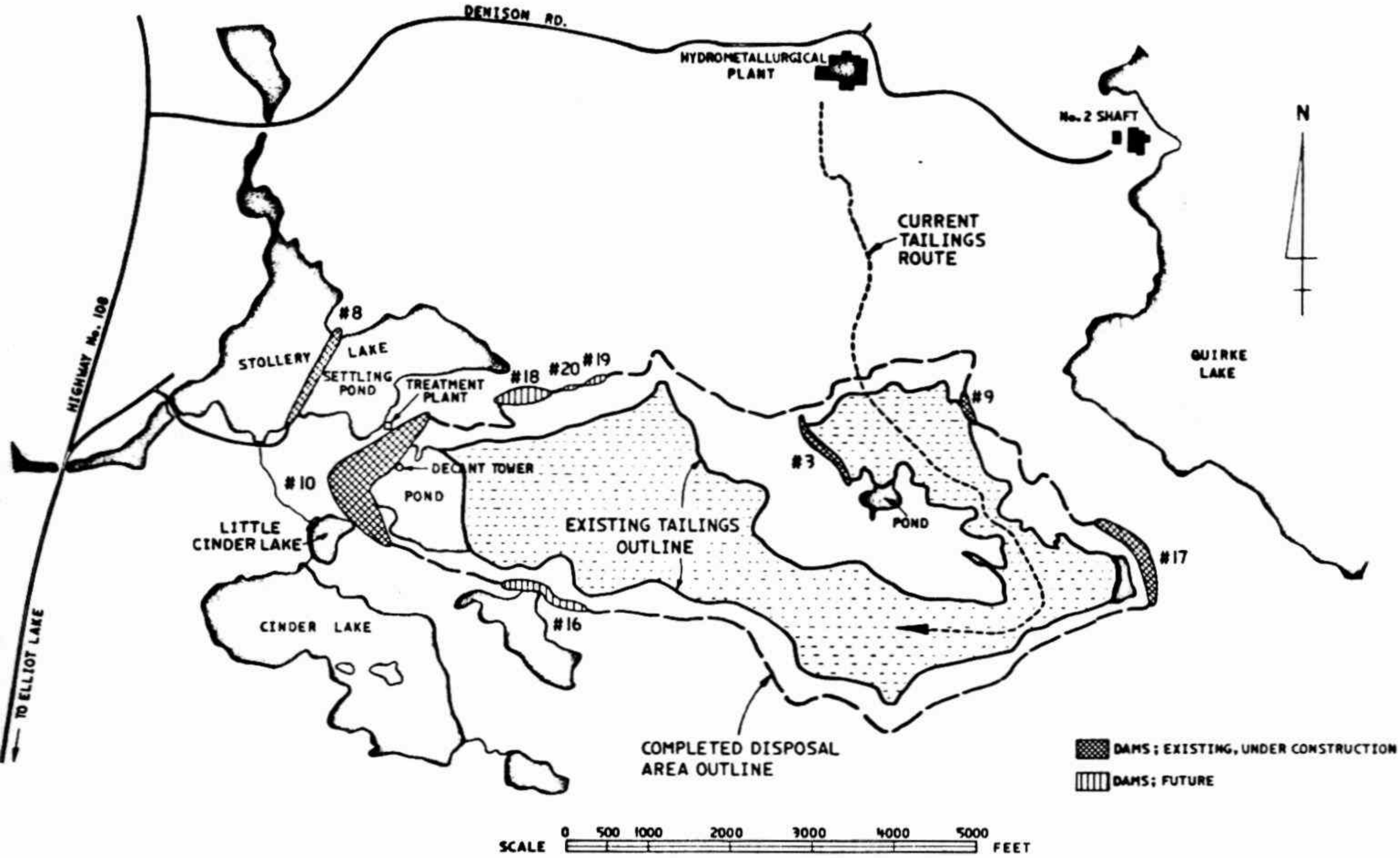


FIG. 12 KEY PLAN – DENISON DISPOSAL AREA

To develop the full potential of the valley, it is necessary to construct several dams across depressions in the valley rim (Fig. 12). The foundation areas of three of the dams (numbered 9, 16 and 17) are relatively near the present tailings level; these are under construction. However, main control is provided by Dam No. 10 located at the extreme west end of the lake; the design and construction of this dam is critical to the scheme. Finally, three small dams (designated as Nos. 18, 19 and 20) will be required in the northwest sector of the basin. Since these structures will protect relatively shallow "saddles" in the rim of the basin, the detailed design and construction of these embankments will not be required for several years.

DESCRIPTION OF TAILINGS DAM No. 17

The design of Dam No. 17 evolved over a period of about three years, during which time the body of information became more refined relative to foundation conditions, construction materials, and the pattern of tailings deposition at the east end of Long Lake. In 1972 a preliminary subsurface investigation was carried out utilizing manual probings and test pits. The key result of this investigation was the discovery of a substantial deposit of relatively impervious glacial till which was considered potentially suitable for the construction of an impervious compacted fill.

Subsurface Conditions: The site is located in the southeast "corner" of the Long Lake basin. The predominant feature along the proposed dam alignment is a hill which divides the site into a northern and southern valley. The northern valley is essentially underlain by sound bedrock. Except for the central hill, which is comprised of sound bedrock, the south valley is underlain by an extensive and homogeneous deposit of very dense and impervious glacial till. The glacial till is underlain by generally sound and relatively impervious bedrock. The groundwater level is at ground surface across the floor of the south valley. A typical stratigraphic section across the dam axis in the south valley is shown on Fig. 13.

The dam is founded either on sound bedrock or on very dense glacial till and, accordingly, it is envisaged that settlement of the proposed dam will be negligible or very small.

The foundations are relatively impervious, the in situ coefficient of permeability of both the glacial till and bedrock being in the order of 10^{-5} cm/sec.

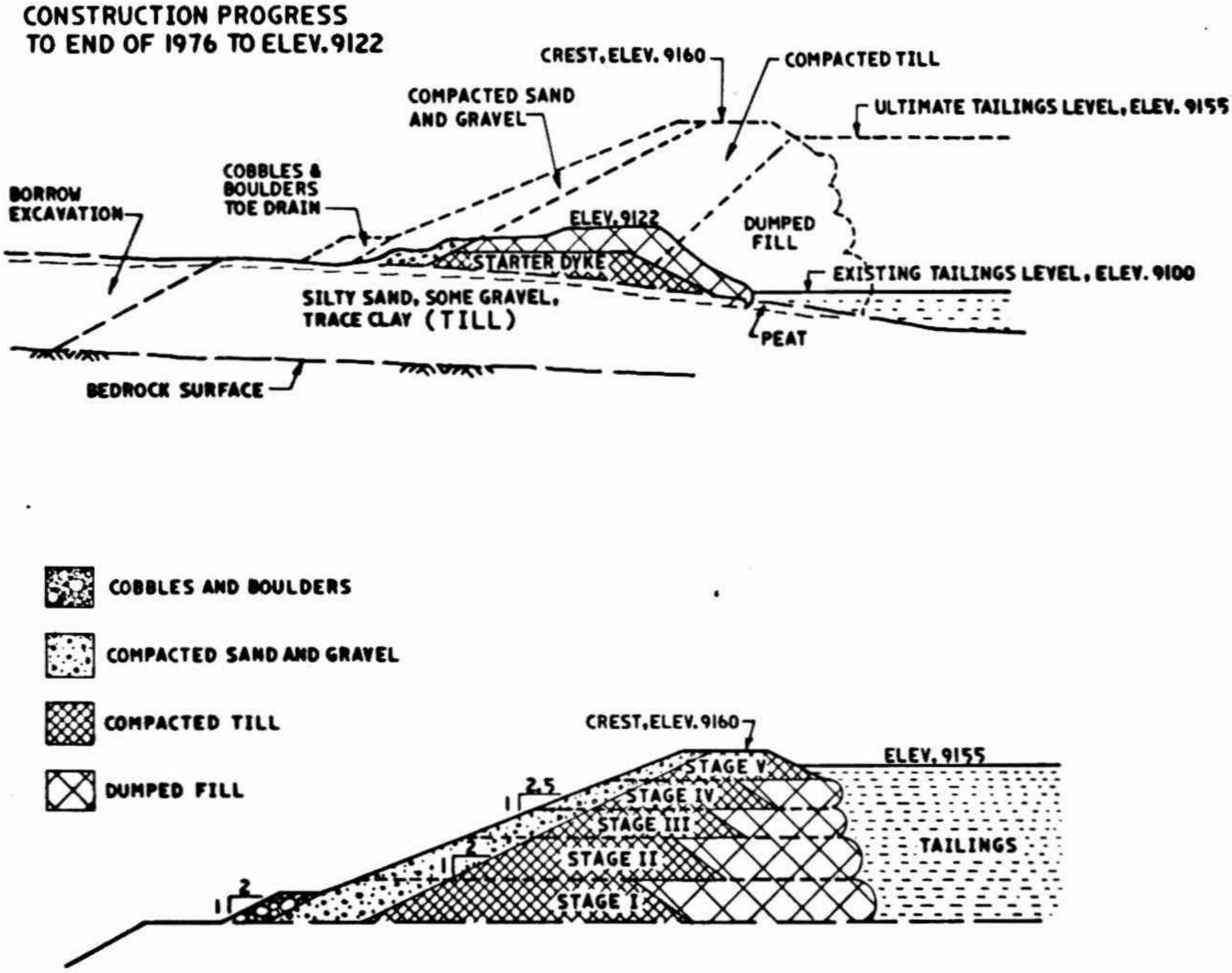


FIG. 13 CROSS SECTION, DAM No. 17

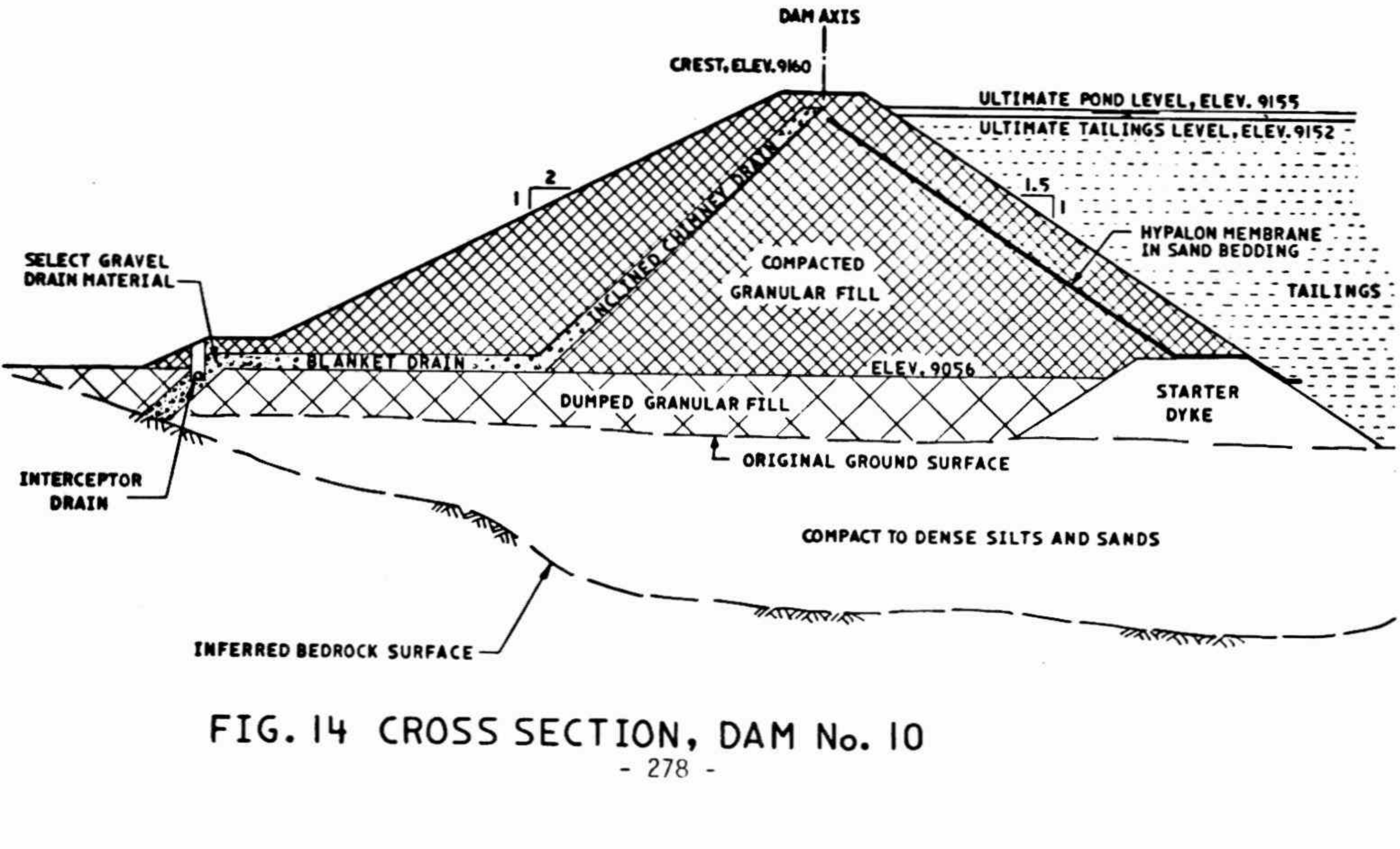


FIG. 14 CROSS SECTION, DAM No. 10

Available Construction Materials: The volume of glacial till available for dam construction is considered sufficient to complete not only Dam No. 17 but also Dam No. 9 adjacent to it. The engineering properties of the till are excellent, producing a fill of high strength ($\emptyset' = 37^{o}$), low permeability ($k \approx 10^{-6}$ cm/sec.) and good compaction characteristics since it exists, in situ, at close to optimum water content.

In addition to the glacial till deposit noted above, large deposits of sands and gravels exist within a few miles of both dam sites.

Properties of Spigotted Tailings: Tailings entering the Long Lake basin are in slurry form and, as such, have the strength characteristics of a viscous fluid. Therefore, for engineering design the undrained shear strength of the unconsolidated tailings is assumed to be zero. Once the tailings have been densified due to the effect of overburden pressure, the materials display the drained strength characteristics of a granular material and become relatively incompressible and impervious.

Choice of Dam Section: Given the properties of the glacial till and tailings noted above, the construction of an impervious dam raised in stages, using the upstream method of construction, was selected (Ref. Fig. 13). The dam consists of a core of glacial till compacted in place and protected by a downstream shell comprised of the necessary drainage zones. The minimum required configuration of the core and downstream filter has been determined using both slip circle and simplified wedge analyses. It should be noted that, for dams raised on a stage construction basis, the stability of the upstream shell is greatly enhanced by the lateral pressure due to the tailings.

Seepage: Due to the relatively impervious nature of the dam foundations, the glacial till dam core, and the tailings themselves, the seepage through the dam and its foundations should be negligible. Due to the topographic conditions downstream of the dam, any seepage which does occur can be readily collected.

Settlement: It is anticipated that settlement of the compacted till core in the order of 2 to 4 per cent of the fill height will occur. However, settlements within dumped zones of till (Ref. Fig. 13) could reach 10 to 15 per cent of the fill height. To densify the individual dumped zones, a surcharge of random fill will be placed on these zones prior to the next stage of impervious core construction.

Quality Control of Till Material: The stability of the dam is highly dependent on the water content of the till material prior to compaction. Therefore, a system of drainage ditches has been excavated to promote precipitation runoff from the impervious

borrow area. Further, the borrow area is developed in such a way as to prevent undue moistening of the glacial till and, during till placing operations, strict control of the water content and compaction of the till is provided.

DESCRIPTION OF TAILINGS DAM No. 10

This dam is the critical control feature of the tailings retention scheme. In contrast to Dam No. 17, the effects of water impoundment, consequent runoff and possible flooding must be controlled. Further, whereas all the other dams can be founded close to, or on, dense natural subsoils or rock, the central portion of Dam No. 10 must perforce be founded in a deep portion of Long Lake on thick lacustrine deposits. This necessitates a radically different form of construction method and design. In addition, in this area, there is a marked lack of impervious fill material.

Subsurface Conditions: Original lake bottom is underlain by granular overburden as much as 20 m (70 ft.) in thickness in the central upstream portion of the dam (Ref. Fig. 14). The predominant soil type which forms the foundation subsoil is loose to compact fine sand to silty fine sand, grading into a sandy silt with depth. The finest grained natural subsoil at the site is a 3 m (10 ft.) thick layer of silt located within the extensive fine sand to sandy silt deposit. Beneath the central area of the dam, where the overburden is the thickest, a coarse-grained layer of sand and gravel overlies bedrock.

Bedrock forms or is very close to ground surface in both abutment areas on either side of Long Lake. Between the abutments and along the dam axis, bedrock drops off into a depression beneath Long Lake where the overburden was found to be thickest. In addition, the bedrock surface is trough shaped perpendicular to the dam axis or along the axis of Long Lake, rising to form a large outcrop outside the downstream toe area of the dam. Bedrock is a massive but jointed quartzite containing diabase dykes. Through pressure packer testing the bedrock was found to have a coefficient of permeability of the order of 10^{-3} to 10^{-4} cm/sec., decreasing to 10^{-5} cm/sec. at the bottom of the respective borings.

The compact natural sediments are considered fully capable of supporting the dam in all stages of construction to its maximum height of about 30 m (100 ft.). In the zone of thickest overburden the magnitude of settlement is estimated to be about one per cent of the fill height. Since the abutments are

essentially underlain by bedrock, the settlement of the dam in these areas will be negligible. The resultant differential settlements do not constitute a problem since the compacted earth fill is relatively flexible and, with stage construction, settlement will be accommodated as the dam is raised in increments.

Available Borrow Materials: An abundance of granular material, in the form of gravelly sand, is available within a few miles of the dam site but practically no impervious borrow had been located at the design stage (1972). The gradation of the material for drain zones within the dam was selected in relation to the grain size distribution of the gravelly sands noted above.

Stability of the Dam - Stage Construction: At current mill production rates, more than 25 years will be required to fill the Long Lake basin with tailings. Accordingly, from a technical viewpoint it is possible to raise the dam in relatively small increments providing that each individual stage is stable.

Adequate provision has been made to ensure the stability of both slopes of the dam. The upstream slope, set at 1.5 horizontal to 1 vertical, will be stabilized at all stages by the weight of the ponded tailings bearing against it. The downstream shell with an outer slope of 2 horizontal to 1 vertical will be protected by an internal inclined chimney drain which will draw the phreatic surface down to the toe collector system (Fig. 14).

The surface of the downstream slope will be protected against erosion by using an outer rockfill zone or by planting and maintaining suitable vegetation.

Seepage Control: Seepage through and beneath Dam No. 10 is controlled in two ways:

i) the magnitude of flow and seepage gradients through the dam are minimized by the provision of a flexible impervious plastic membrane known as Hypalon:

ii) the direction of flow is controlled in that seepage is positively collected and channelled toward a location where it can be chemically treated.

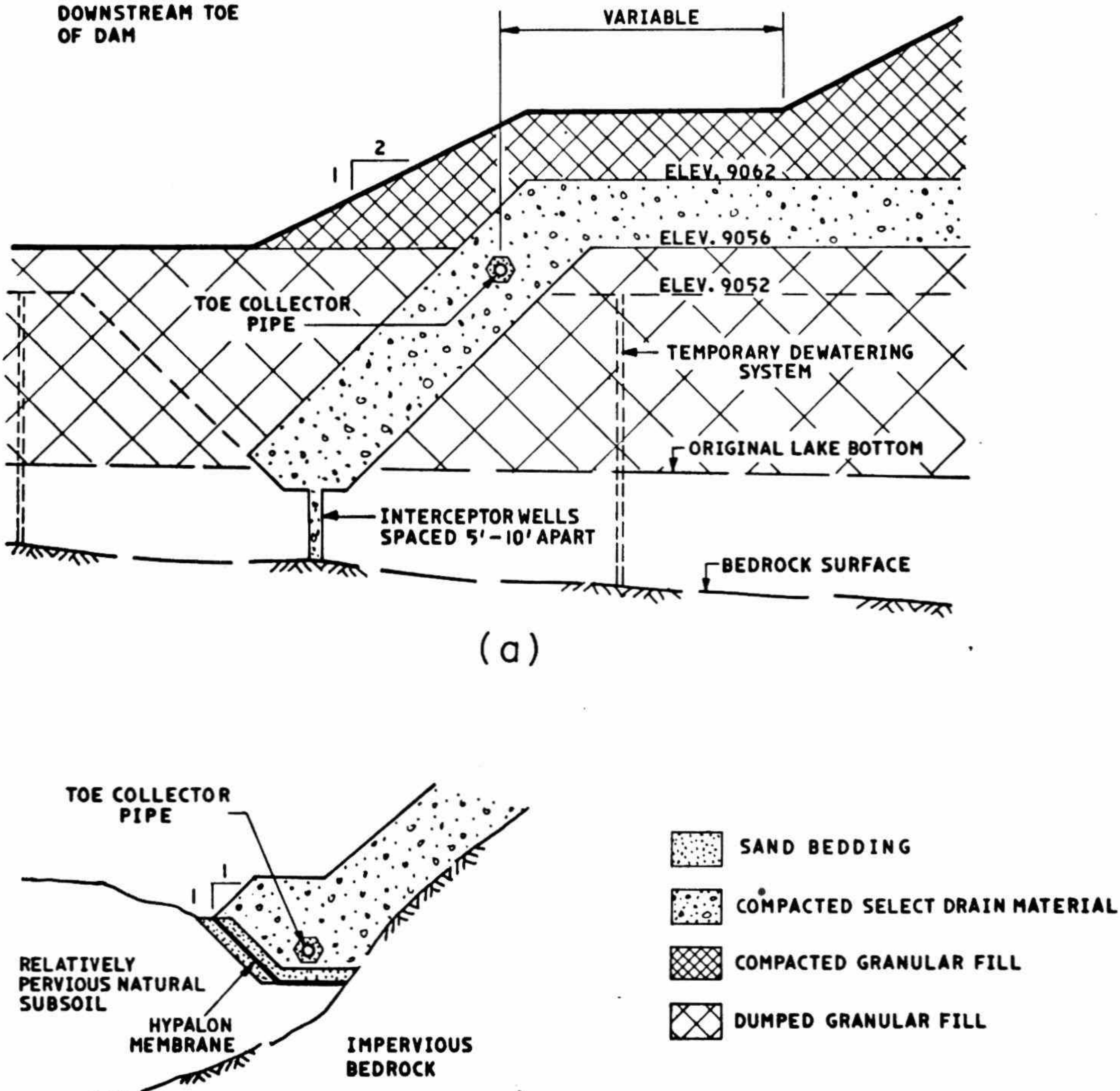
The Hypalon membrane was first installed in 1971 and consists of a monolithic sheet of flexible plastic which extends across the upstream shell of the dam (Fig. 14). Due to the presence of tailings and overburden in the central portion of the dam, the upstream edge of the membrane could not be extended to bedrock and was, accordingly, set into the upper surface of

the tailings. Within the abutment areas the Hypalon was fixed to the underlying bedrock. Thus, seepage passing by the dam is forced to flow down through the tailings to pass the bottom edge of the Hypalon membrane.

To minimize seepage gradients within the downstream toe of the dam and to channel all seepage toward the chemical treatment plant, a perforated pipe drain bedded in graded filter material has been provided. The size of the pipe is based on estimated seepage flows. To ensure that all seepage passing beneath the dam is collected, an interceptor zone, consisting of select drain material, extends down from the collector pipe to the bedrock surface. In zones where bedrock is locally deeper, the interceptor zone is supplemented by a series of interceptor wicks or wells, filled with pea gravel, which serve as gravity relief wells (Fig. 15(a)). The alignment of the toe collector system has been chosen to follow the optimum contours of bedrock surface underlying the dam.

To ensure that all seepage is channelled into the toe collector system, it is necessary that a seepage "barrier" be provided downstream of the toe collector pipe. Within the abutment areas, the pipe is placed in a shallow ditch which will positively "trap" all seepage. To prevent escape of seepage toward Little Cinder Lake (Fig. 12), the outlet to that lake was dammed, raising the lake to a level which is about 2 ft. above the highest portion of the collector pipe in that sector. A massive bedrock outcrop located downstream of the central portion of the dam acts as a barrier in this zone. Finally, some small impervious dykes and sheets of Hypalon have been provided between the toe collector pipe and Stollery Lake to ensure that all seepage is channelled toward the treatment plant (Fig. 15(b)).

Decant System: To supplement the "horizontal" decant tunnel which passes beneath the dam, the water level in the tailings pond will be controlled by a vertical 1.2 m (4 ft.) dia. prestressed concrete pipe which is installed in stages as the tailings level rises and the dam is raised. To assess the capacity of this system to control runoff from a severe storm, a hydrological study was carried out. The results of this study indicated that, for the regional design storm known as the Timmins storm, the headpond level would rise from elev. 9065 (operating level 1971 to 1976) to elev. 9073.5, a distance of 8.5 ft. The estimate of elev. 9073.5 was based on an efficiently operating anti-vortex entry on the top of the tower. To that end, a suitable entry/trash rack system has been designed.



(b)

FIG. 15 TOE DRAINAGE COLLECTOR SYSTEM, DAM No. 10

Construction Progress: Since 1971, raising of Dam No. 10 has continued on a stage basis. A schematic outline of the construction to date is shown on Fig. 16. In 1971 and 1972, the key elements such as the Hypalon membrane, toe collector system and the base of the chimney drain were constructed under the field supervision of Golder Associates. Raising of the body of the dam has been carried out and monitored by Denison Mines Limited, who carry out compaction control and gradation analyses during construction periods. The schedule of tailings impoundment behind Dam No. 10, as initially anticipated, called for raising the headpond in 5 ft. increments on an approximately annual basis for the period 1971 to 1981. However, the buildup of tailings behind Dam No. 10 has been much slower than originally envisaged and, consequently, heightening of the decant tower was not necessary until May 1976. Accordingly, in June and July 1976, with the addition of the first tower segment, the headpond level was increased from about elev. 9066 to elev. 9070.

Performance of Hypalon Membrane: To monitor the performance of Dam No. 10, a number of piezometers and standpipes were installed within the dam in 1972. Water level measurements were obtained in these instruments on a periodic basis.

The water levels determined in the piezometers and standpipes at a typical section from 1972 to the present are shown on Fig. 16. During the period March 1972 to June 1976 a gradual decrease in water levels has been noted. The magnitude of this decrease ranges from several inches to as much as about 2 ft. (Ref. Piezometer 521).

For the data obtained after the commencement of pond raising (June 9, 1976), it was noted that:

i) The water levels within the dam generally rose during pond raising at a rate which closely followed the headpond level increase; i.e., there was no significant lag in the response of the piezometers and standpipes.

ii) Before pond raising, the water level within the dam was below an imaginary straight line drawn between the headpond level and the toe drain pipe (for location Ref. Fig. 16). The water levels determined after pond raising (mid-July 1976) are proportionately even further below the imaginary straight line drawn from the new headpond level. In general, although the headpond level was raised by 4 ft., the observed increase in water level within the dam was only 2 to 3 ft.

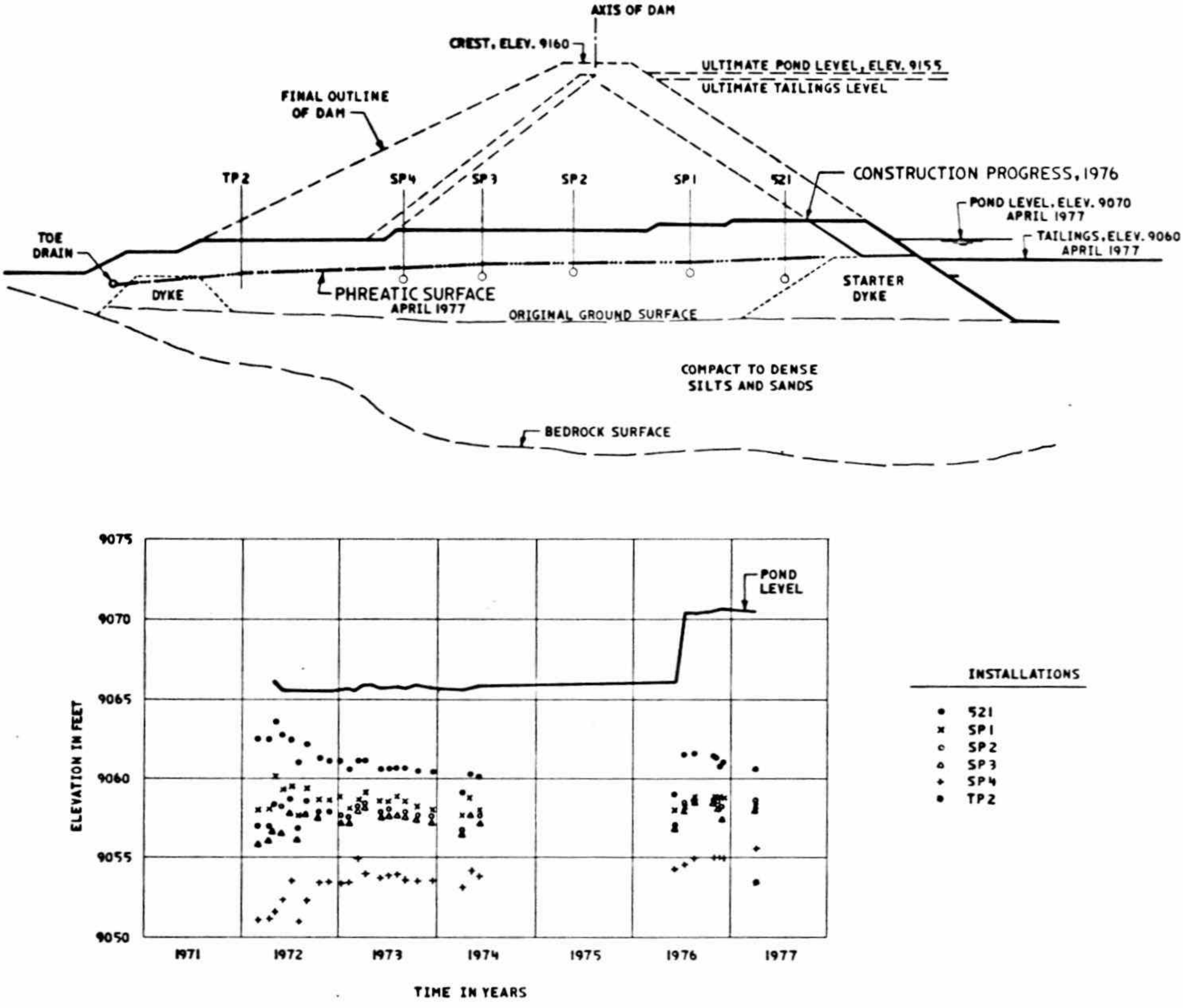


FIG. 16 SEEPAGE CONTROL LEVELS, DAM No. 10

Based on the above information, it is apparent that raising of the headpond level has been successful and that the beneficial effect of the Hypalon membrane has been confirmed.

As noted above, the water levels within the dam gradually decreased during the period 1972 to 1976. It is inferred that this decrease is due to the accumulation and densification of the tailings adjacent to the upstream edge of the Hypalon membrane, which has resulted in an improved "seal" between the edge of the membrane and the tailings.

During pond raising, the water level in the dam rose modestly to elevations which are considered well within the limits of safety for the dam. Further, both the elevation and the observed change in water levels downstream of the Hypalon membrane reflect the presence of the relatively impervious membrane.

ABANDONMENT OF TAILINGS DISPOSAL AREAS

Design for abandonment in almost every case necessitates the initial provision of at least one well engineered control dam and decant system designed in accordance with the principles discussed in the paper. This control dam serves as the main feature not only to handle surplus water or liquid during milling operations but as the control for surface runoff or groundwater following cessation of milling.

The commitment to abandonment is therefore made in the earliest stages of design of the waste disposal system in relation to the site selection, assessment of present and future possible seepage regimes, mode of disposal and design of retaining dykes. It costs much more to modify facilities at a later date than to incorporate them into design from the outset.

D'Appolonia et al (1973) consider the principal design considerations for abandonment to be related to water. These may be summarized as:

i) Streams

Storm runoff and stream control can be most expensive initial long-term cost item
Consider effects of reasonable design flow in locating embankments and structures
Develop baseline quality data for streams prior to placement of wastes

ii) Local Surface Runoff

<u>Rule</u> - where possible, divert surface waters away from waste disposal area

Use stream diversion, peripheral ditches, underdrain pipes

iii) Infiltration of Rainfall onto Disposal Area

Consider the use of impervious cover material

Provide final grading for rapid runoff

Provide impervious and erosion-resistant intermediate ditches to direct water off of the waste area

iv) Seepage from Waste Area into Groundwater

Remedial measures to eliminate leachate seepage to groundwater is costly or practically impossible

Minimize groundwater infiltration by sealing original ground, sealing waste surface and collecting in underdrain prior to entering groundwater

v) Groundwater Seepage into Waste Area

Construct adequate underdrain system

Provide rock and/or pipe collectors at major spring areas

Consider separation of uncontaminated underdrainage and leachate to minimize treatment

The treatment of the solid wastes remaining behind the dam will require the provision of a ground cover suitable not only to prevent erosion by water and wind, but to shed rainwater in a "clean" form and also to provide sufficient thickness to inhibit hazardous radioactive emissions. There are presently under study a variety of methods including the use of physical soil cover, growth of vegetation and chemical treatments. The choice of an optimum method is dependent on the topography and specific chemistry of each site. The future in this respect looks promising.

The case history example at Denison has been based on the necessity of controlling water from the outset. The location within a relatively impervious bedrock "rim" is significant in that major control is provided through the seepage collection

measures at Dam No. 10 and treatment in the settling pond (Stollery Lake). This system allows future abandonment in a controlled manner.

The paper has discussed the essential geotechnical principles for design of safe waste disposal areas. The case history discussed exemplifies application of the major principles not only for present disposal but also for abandonment. Waste disposal systems which are built without recognition of the problems, largely associated with the control of water, are unacceptable. While the costs of abandonment are certain to rise markedly in the years ahead, they can at least be kept in reasonable proportion by the selection of the most suitable sites in keeping with sound design principles.

ACKNOWLEDGMENTS

The authors wish to acknowledge the co-operation of the staff of Denison Mines Limited; in particular, Mr. M. J. de Bastiani, P. Eng., Vice President of Technical Operations. Further, the assistance of Golder Associates' staff members, Mr. M. H. Wright and Mrs. J. E. Morrad, is appreciated.

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SESSION V

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THE QUEBEC METRO INCINERATOR

J. F. Stevens

INTRODUCTION.

The idea of installing a large central incinerator plant in Quebec began back in 1968 when many of the municipalities surrounding Quebec City became concerned about the disposal of their municipal wastes. Land fill sites which had served for years would soon be filled to capacity and with an increasing population bringing increasing refuse generation to the municipalities, it was decided by a group of the municipalities to have an engineering consultant study the problem. At about the same time the City of Quebec was concerned about the costs involved in maintaining a twenty-five year old incinerator plant that was not large enough to serve their requirements, and further was not designed to suit the new pollution requirements that were being established.

Various methods of refuse disposal were studied by the Engineering Consultants including composting, sanitary land fill, and incineration. It was recommended that a central incinerator plant be installed, preferably with heat recovery and equipped with gas cleaning equipment in the form of electrostatic precipitators. The Quebec Urban Community (C.U.Q.), formed in 1970, carried on with this study and investigations since now the population that would be served by a central plant amounted to approximately 425,000 inhabitants. Representatives of the C.U.Q. and their consultants visited steam generating incinerator plants in North America and Europe and concluded that the technology was a well proven one and could be built to suit their particular requirements. It

was early recognized that, in order to reduce the costs per ton of incineration of refuse to the C.U.Q., the steam energy produced by the plant must be sold, that is - a secured steam market was required. Many steam consumers in the area were investigated with the result that a long-term steam agreement was signed between the C.U.Q. and Reed Paper (formerly Anglo Canadian Pulp and Paper) to take all the steam produced by the incinerator plant. Following this agreement, tenders were called by the consultants on the combustion and mechanical portion of the plant and our firm was awarded the contract in December 1971 to install the 4 - 250 Ton per day Von Roll units. The civil portion of the plant was tendered separately about six months after the award of our contract, thus allowing the civil work to be tendered to suit the selected mechanical equipment.

THE MASS BURNING SYSTEM.

The incineration system installed in Quebec is known as the 'mass burning system' or the 'on grate system' where municipal refuse is burned in grate boiler type furnaces in the condition which the householder puts it out for collection. There is no pre-sorting, pre-shredding or pre-handling of the refuse at the incinerator plant prior to its entry into the furnaces. The possible exception to this would be large items such as chesterfields, bed frames, chairs, refrigerators, etc., that will not pass through the feed chutes to the furnaces. In this case material of this type is set aside by the crane operator and, as required, sheared by a bulky waste shear to reduce its size for entry to the furnaces. This is usually done about once a week.

There is no question that municipal refuse can be considered as an ideal fuel for boilers, it is physically non-uniform, varies in heat content on a daily and seasonal basis as well as from city to city, indeed even district to district within a city. In order to ensure high quality combustion and proper burn-out of the refuse, special boilers and grates must be used. The mass burning system has been used for more than twenty-five years in Europe and Japan so that the technology developed over these years of experience has produced boiler and grate designs that can be used to derive efficient, clean and odorless refuse heat energy. This combustion can take place without the need to add oil, gas or coal to the process.

THE REFUSE TO ENERGY PROCESS.

The Quebec incinerator has a total capacity of 1000 Tons per day and consists of 4 - 250 Tons per day furnaces, each designed to operate under the following conditions:-

Refuse burning rate	10.4 T/hr.
Steam Production peak	81,000 PPH.
Feedwater temperature	287° F.
Steam pressure at S.H. outlet	680 psig. ± 20 psig.
Steam temperature	600° F. $\pm 25^{\circ}$ F.
Gas temperature at boiler outlet	480° F.
Combustion air temperature	60° F. min.

The combustion of refuse in the plant takes the following steps. (See Figures Nos. 1 and 2)

1. Weigh Scale - Vehicles entering the plant are weighed electronically in and out.

2. Ramp Road - Vehicles proceed from the weigh scale up the two-way ramp road to the enclosed tipping floor.

3. Tipping Floor - The tipping floor is designed to handle the traffic for trucks and trailers up to 60 ft. long at multiple unloading stations. This area of the plant is completely enclosed and designed to operate under a slight negative pressure. Vehicles discharge into the refuse pit in accordance with signal lights operated by the refuse crane personnel.

4. Refuse Pit - Refuse is dropped into a concrete pit having a storage capacity of approximately 2900 tons, based on a refuse density of 702 lbs./yd^3.

5. Refuse Crane - An overhead travelling refuse crane, remotely operated from an air-conditioned control cabin, charges the incinerator feed hoppers.

6. Feed Hoppers - Refuse is fed to the incinerator by means of feed hoppers and water-cooled chutes. Vibrating feed hoppers with isotope level controls are installed to ensure a more even flow of refuse to the feed hoppers and then to the incinerator grates.

7. Grates - The feed chute delivers the refuse directly to hydraulically operated grates where it is moved through the furnace in a three grate step type system, to the final stage of discharge of ash to the residue conveyors.

8. Residue Conveyors - Residue discharged from the grate system drops down a water-cooled chute into a submerged drag scraper conveyor, where it is immediately quenched. Similarly, riddlings which pass through the grate bars are directed into the submerged drag scraper conveyor by means of riddling chutes fitted to the bottom of the undergrate hoppers. The drag scraper conveyor discharges residue into the residue pit.

9. Residue Pit - Residue from the drag scraper conveyor is deposited in the residue pit. An overhead travelling crane services this pit and is designed to transfer residue to dump trucks. The design allows for truck traffic to enter at one side of the building and exit at the other side of the building. A metal reclamation system can be added to this area if required.

10. Integral Boiler - The boiler is a natural circulation type, specially designed to suit the firing of refuse in a raw state. It is an integral part of the incinerator design, and converts the heat energy given up by the combustion process on the grates to steam for process steam, district heating or electrical power production.

While special design considerations must be given to the design of a refuse fired boiler, it is to be noted that the incinerator boiler contains the fundamental elements such as a radiant furnace section, convection section and economizer section found in a conventional fuel fired boiler. In this way, the valuable heat given up in the radiation chamber contributes to the overall efficiency of the boiler unit as it does in a conventional boiler. Mechanical rapping hammers electrically driven are installed in the convection and economizer sections to ensure clean tube surfaces and continued high boiler efficiency. Further, this system of tube cleaning provides for lower operating and maintenance costs than the conventional steam operated soot blower system. Steam produced in the boiler tubes is collected in a generously sized steam drum where moisture separation takes place to ensure dry steam for delivery to heating and process requirements. The flue gases leave the boiler at approximately 480^{o} F. and enter the electrostatic precipitator.

11. Electrostatic Precipitator - The electrostatic precipitator installed behind each incinerator boiler is designed to efficiently remove solid particulate matter leaving the precipitator is 0.2 lbs./1000 lbs. of dry gas corrected to 50% excess air. The flue gases leaving the precipitator enter the induced draft fan.

12. Induced Draft Fan - The boiler and precipitator system operates under a negative draft created by the induced draft fan behind each incinerator unit. The fans are of the radial tip blade design, being specifically designed for incinerator application. Flue gases leaving the induced draft fan are drawn through the breeching system to the stack.

13. Ducting and Stack - A system of gas ducting connects the outlets of the individual induced draft fans to a common stack.

14. Bulky Waste - A Von Roll bulky waste hydraulically driven shear is installed in the plant. This shear is located at the tipping floor level and the sheared material is delivered to the refuse pit where, because of its reduced size, it is ready to be sent to the furnace along with the other refuse in the pit. While most municipal refuse is of a size that will fit the charging hoppers, occasionally some bulky material such as chesterfields, beds, mattresses, etc., are delivered along with other refuse to the refuse pit. The usual method of handling this situation is separation by the pit crane operator, stacking the bulky material at one end of the pit and, as required, delivering the bulky material to the shear. (See Figure No. 3)

SPECIAL FEATURES.

Mechanical Rappers. Of particular interest in this boiler design is the use of mechanical rappers to maintain clean tube surfaces in the convection sections of the boiler. The particular boiler design used in Quebec is known as a 'tail end boiler' and the convection sections consist of a series of top supported vertical panels, the heating surfaces being at right angles to the gas flow. Mechanical hammers, weighing approximately 16 lbs. each, are positioned on a rotating shaft and each hammer strikes a spring-loaded pin which in turn strikes the rapper pad located on each tube panel. Three shafts with hammers serve the superheater, evaporator and economizer sections of the boiler. Shafts are rotated by electric motors with push button controls and timers. In general, each panel is rapped 9 times over a 3-minute period. This operation is usually performed twice a shift, but may vary depending on the area to be cleaned. The advantage of this system of cleaning boiler tubes is increased thermal efficiency and long operating periods without shut down for cleaning the convection surfaces.

Residue Pit. A residue storage pit is located at the discharge of the clinker conveyors. This allows for residue hauling to take place on an 8-hour day basis, 5 days a week. Without a storage pit of this type ash removal tracks must be on hand 24 hours a day to ensure continued plant operations.

SUMMARY.

I don't think that there is any subject more widely discussed today than the treatment of our waste products, be they sewage sludge, industrial wastes, hazardous waste or municipal refuse. Our recent high energy costs have undoubtedly accelerated this interest, particularly when you consider that three pounds of common household refuse has the heat value of one pound of coal. The mass burning process which I have described is one that has been used for years in many parts of the world and recovers energy in the form of steam. Steam, like any recovered resource, must have a market and this market must be secured before the plant is sited, so that the market can be served within a reasonable radius of the incinerator plant. A steam process load such as exists in Quebec with Reed Paper is an ideal steam load for a municipal incinerator plant.

The disposal of our waste products in an environmentally acceptable manner is, of course, the prime objective in a facility of this type. In order to reduce the costs per ton of disposal, attention is given in any facility to whatever resource recovery can be achieved at the plant. It is easily seen that with present day conventional fuel costs that a conservative value for 1000 lbs. of steam is of the order of $2.50. The system which I have described will generate approximately 6000 lbs. steam from 1 ton of domestic refuse, that is a steam revenue of $15.00 per ton of refuse can be achieved at present day conventional fuel costs. In addition minor contributions can be realized if the plant is equipped with ferrous metal separation equipment on the residue end of the system. The markets, however, for this type of resource recovery - as indeed with other recovered

resources - are by no means as stable and as lucrative as the steam recovery route because of our energy demands and our high energy costs.

The Quebec Incinerator is located approximately 1500 feet from a steam consumer which can accommodate all the steam produced by the incinerator plant. Many of the European plants which I have visited generate electricity during the summer months and use steam for district heating and/or process during the winter months. While power generation is feasible all year, and using exhaust steam from the turbine for district heating, the economics of such a plant, while justifiable in European countries, may not apply here because of our present low power costs. There is little doubt that this situation will change as our electric power costs increase, so that power generation from refuse fired boilers will be a fact in North America in the 1980's.

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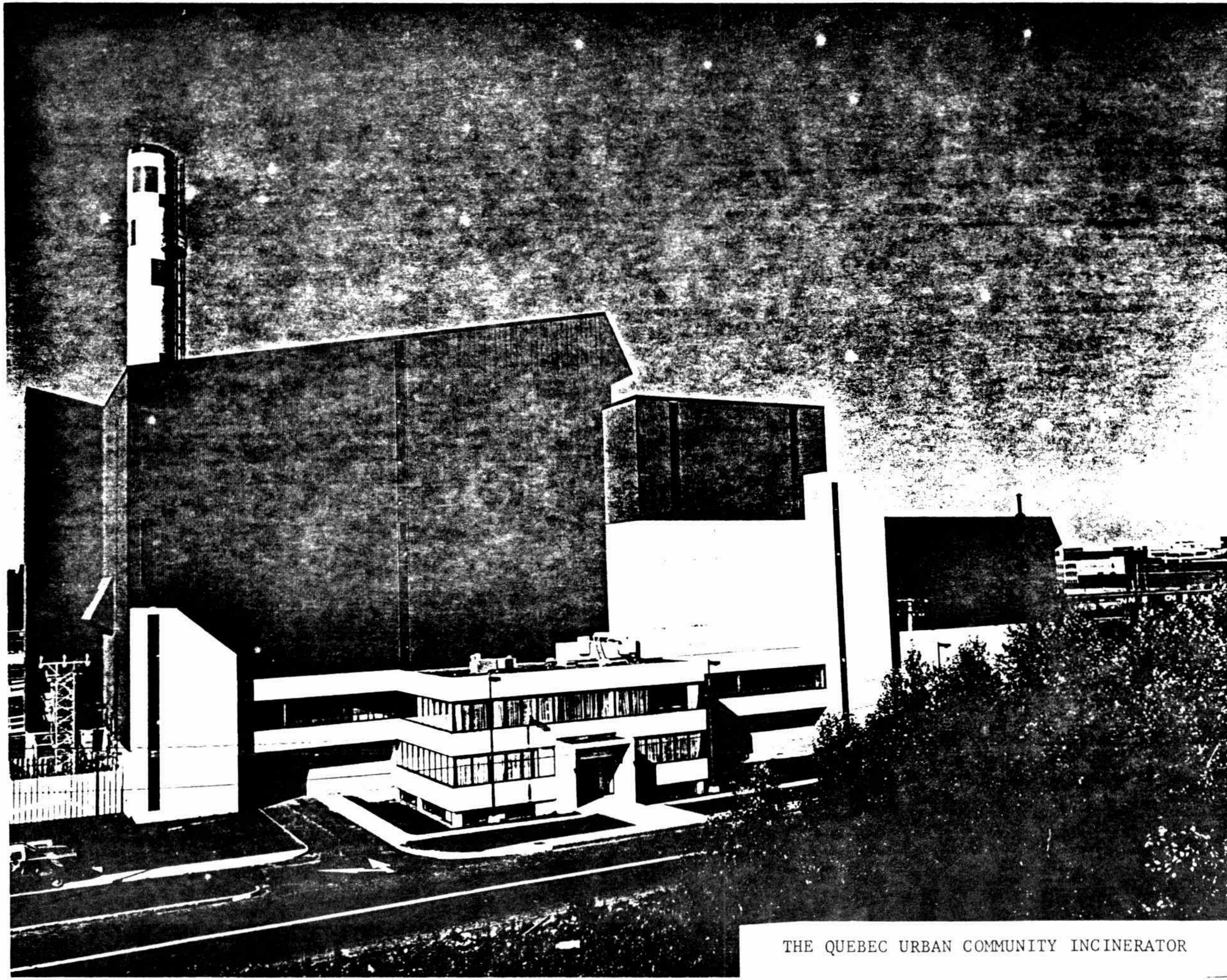
Acknowledgments --

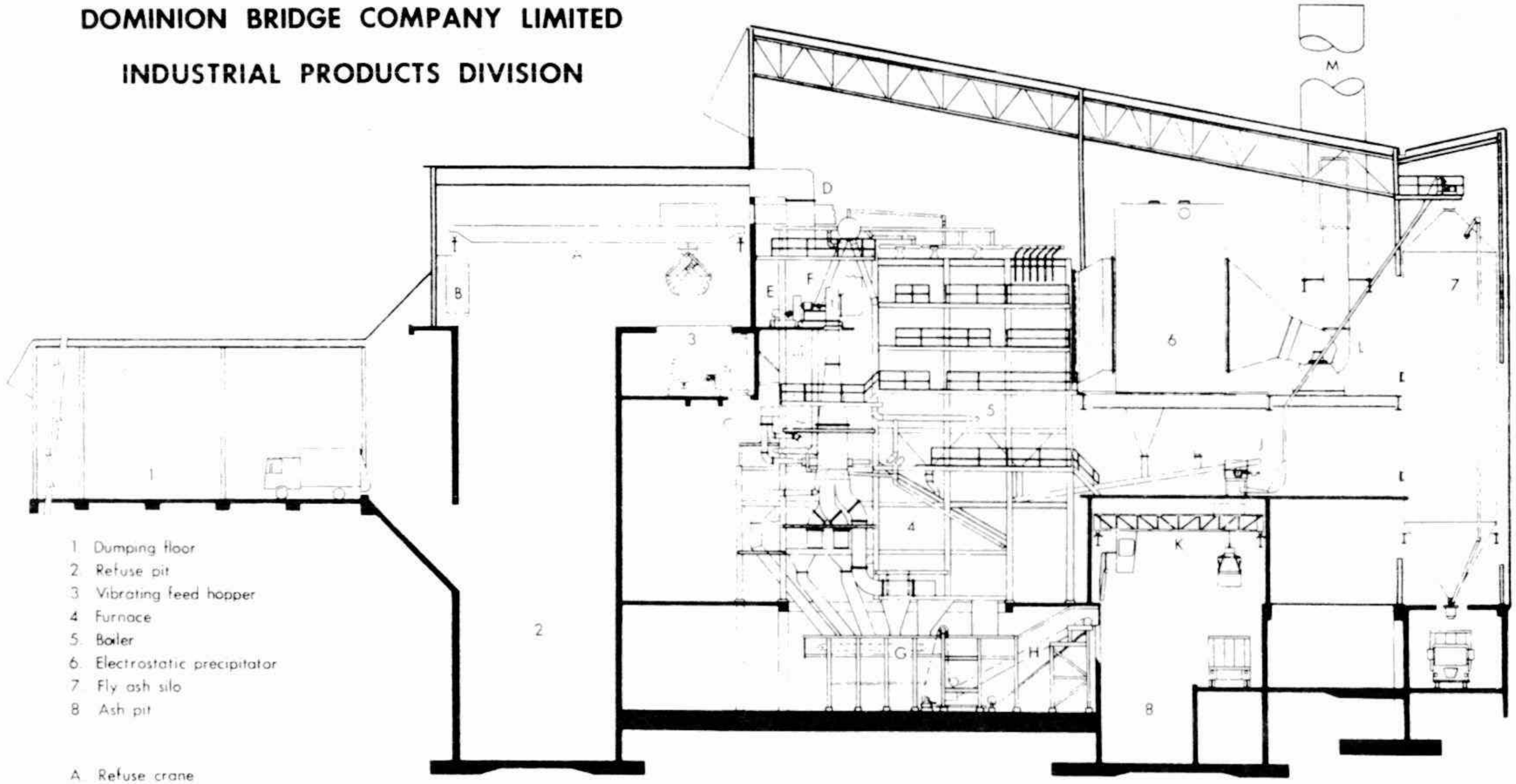
The assistance of Messrs. H. Aubin and R. Rinfret of C.U.Q. in providing data for this paper is gratefully acknowledged.



THE QUEBEC URBAN COMMUNITY INCINERATOR

DOMINION BRIDGE COMPANY LIMITED

INDUSTRIAL PRODUCTS DIVISION



1. Dumping floor
2. Refuse pit
3. Vibrating feed hopper
4. Furnace
5. Boiler
6. Electrostatic precipitator
7. Fly ash silo
8. Ash pit

A. Refuse crane
B. Refuse crane control cabin
C. Water cooled chute
D. Combustion air inlet ducts
E. Over fire air fan
F. Primary air fan
G. Riddling conveyor
H. Clinker conveyor
J. Fly ash conveyor
K. Ash pit crane
L. Induced draft fan
M. Stack

Quebec Urban Commission

Incinerator

FIG. No. 1

0 8 16 24

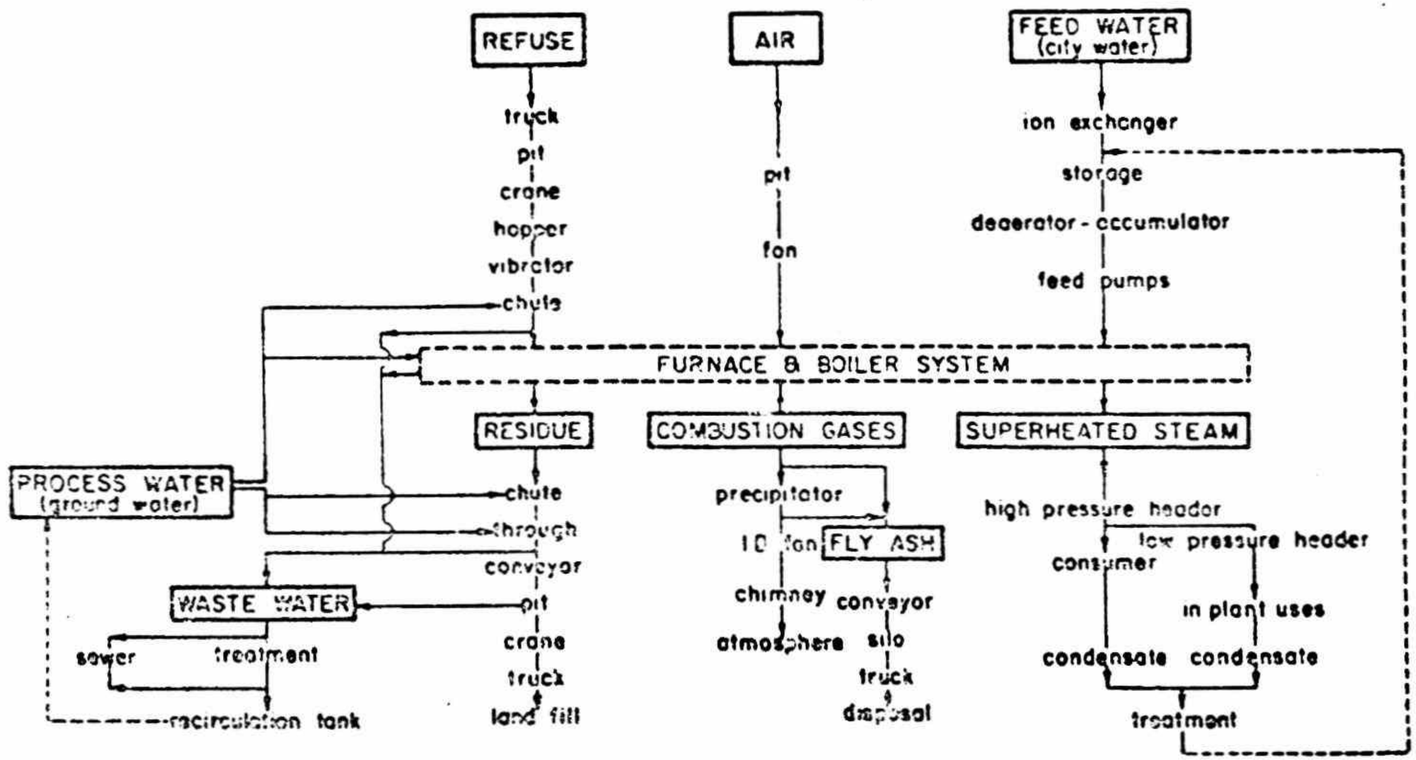


FIG. No. 2

FLOW DIAGRAM – QUEBEC INCINERATOR PLANT

Dimensions

Width	13 ft.
Length	26 ft.
Height	13 ft.
Weight	40 tons
Feed opening	11 x 12 ft.

Technical Data

Drive	electric-hydraulic
Power requirements	50 HP.

Capacity

Crusher volume	700 cu. ft.
Cutting width	1 ft.
Capacity	4250-7000 cu. ft./hr.

1 **Inlet**
2 **Discharge**
3 **Hydraulic Drive**
4 **Cutting Edges**

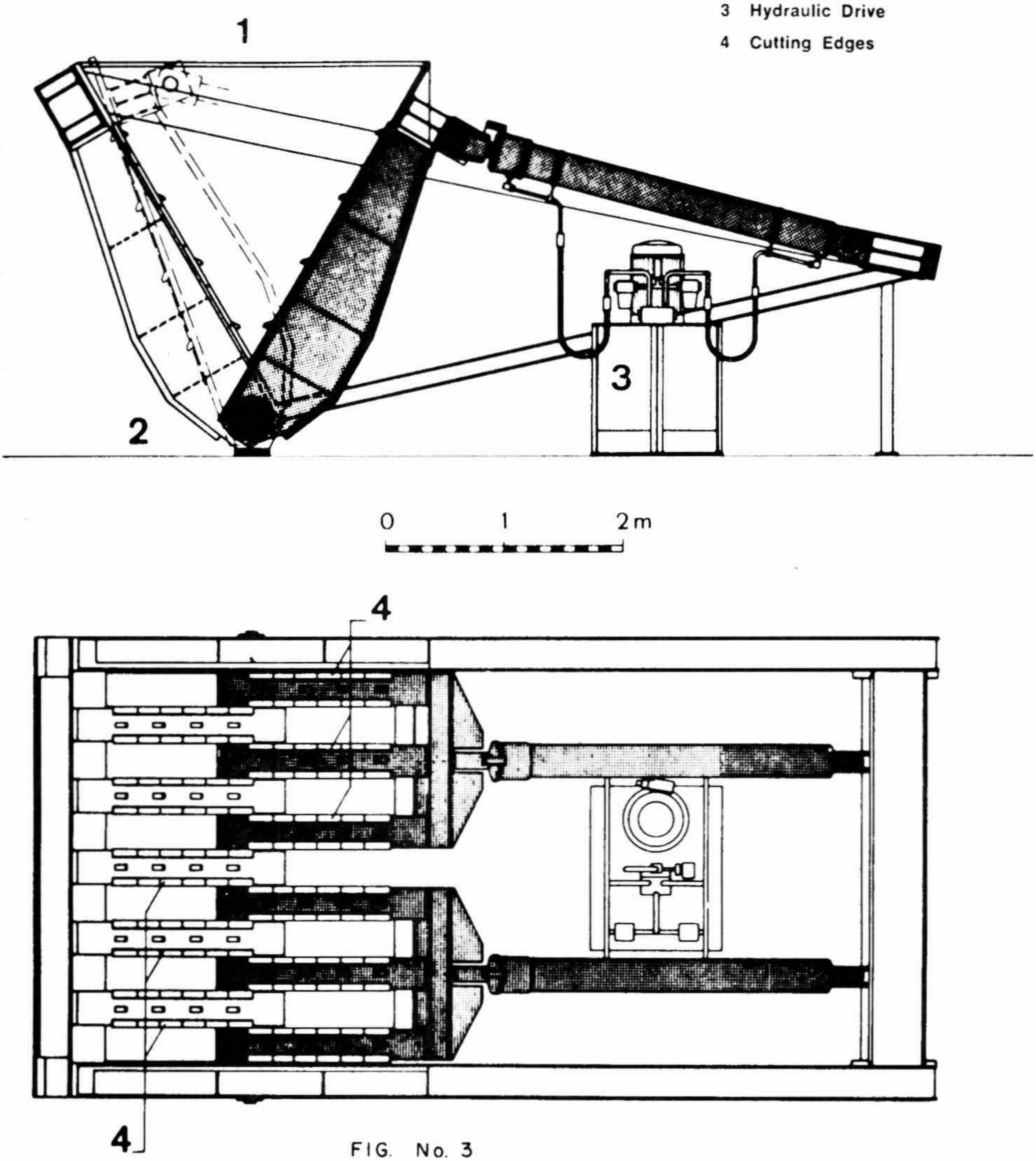


FIG. No. 3

C.U.Q. INCINERATORS

QUEBEC CITY, QUEBEC

GENERAL INFORMATION

B.L. Borovskis

March 24, 1975

DOMINION BRIDGE COMPANY, LIMITED

INDUSTRIAL PRODUCTS DIVISION

C.U.Q. INCINERATORS

GENERAL INFORMATION

1. Incinerator System with Steam Generation

Rated Capacity	250 T/D x 4 Units = 1000 T/D
Minimum Capacity	125 T/D per Unit
Refuse (Design Condition)	HHV 6000 BTU/lb., LHV 5400 BTU/lb.
Refuse Volume Reduction	Approx. 85%
Steam Production	81,000 lb./hr. Maximum @ 680 psi & 600^{o}F.
Unburned in clinker	Maximum 5% by weight
Putrecibles in clinker	Maximum 0.3% by weight
Site	191,350 sq.ft. (Approx. 550' x 360') OR 4.4 Acres
Roof Area	47,600 sq.ft.
Population	Quebec City - 186,088 - 1971 Census
	Metro Quebec - 480,505 - 1971 Census
Total Plant Staff	Approx. 50 persons
Operation	24 Hrs./Day x 7 Days/Wk.
Steam Generation	3 - 4 lb. steam/lb. refuse

2. <u>Weight Scales (2)</u> - 10' x 60'

Capacity	60 Tons
Records	Truck No., Weight, Date & Time

3. <u>Dumping Floor Ramp Access</u>

Ramp	24' x 550' x 35.5 Rise (2-way traffic)
Door	22' x 14' h., photocell operation

4. <u>Shop & Stores Floor Ramp Access</u>

Ramp	24' x 295' x 17' Rise
Door	22' x 14' h.

5. <u>Dumping Area</u>

82'-9" x 168'

Negative pressure to maintain dust and odours

12 roof mounted heaters to maintain minimum 60^{o} F.

1600 CFM air curtain at door

8 dumping chutes

6. <u>Refuse Pit</u>

31'-5" x 186'-6" x 80' deep

Capacity - 15,750 cu. yds. or 3,280 Tons
OR Approx. 3 days storage

7. Refuse Cranes (2)

Lifting Capacity	6-1/2 Tons
Bucket Capacity	4 cu. yds. (Refuse 400 lb./cu.yd.) OR Approx. 1600 lbs. Each capable of feeding 4 Units (10.5 x 4 = 42 tons/hour)
Hoisting Motor	125 HP, 1200 RPM
Trolley Motor	15 HP, 1200 RPM
Gantry Motor	60 HP, 1200 RPM
Total Crane Weight Including Bucket	46 Tons

Bucket loads indicated and recorded automatically in crane cabin

8. Crane Operator's Cabin

Two Control Stations, air conditioned and climate controlled

9. Waste Shear (Crusher) (1)

12"Strips Approx.

Opening	Approx. 10' x 11'
Hydraulics	50 HP, 1750 RPM Nominal - 2150 psig Maximum - 2500 psig

10. Refuse Hoppers (4)

Opening	10'-6" x 13'

11. Vibrators (4)

Operated by Radio-isotope control to maintain chute level

Drive	15 HP, 900 RPM
Frequency	16 cps

12. Refuse Feed Chutes (4)

Throat	3'-3" x 7'-9"
Water Cooled	

13. Grates (Predry, Main, Finishing) (Four Sets)

Inclined at 15^{0} from horizontal

Total surface - 453 sq. ft.

Frequency - 0 to 4 cycles/minute

8 fixed and 7 moving elements

Drive - hydraulic - max. pressure 2200 psi

Predry	9'-10-1/2" x 9'
Main	9'-10-1/2" x 18' equipped with 7 knives
Finishing	9'-10-1/2" x 18'

14. Boilers (4)

Top supported natural circulation type with Economizer and Superheater

Design pressure 775 psi

Operating pressure 680 psi

Feedwater Temperature 287^{0} F. (Min. 50% Condensate return)

Maximum Steam 81,000 lb./hr. per Unit

Total Heating Surface	28,145 sq.ft.
Economizer	10,100 sq.ft. (28 panels)
Evaporator	16,235 sq.ft. (44 panels)
Superheater	1,810 sq.ft. (8 panels)
Steam Drums	4'-6" dia. x 21'-6"

15. Boiler (Convection Zone) Walls

9" walls composed of steel casing, 4-1/2" of castable insulation and 4-1/2" of castable refractory

16. Upper Furnace Walls (Tube Plate Wall Area)

7-1/2" walls composed of steel casing, 3" wool, 3" tubes and 1-1/2" plastic refractory

17. Lower Furnace Walls

16" walls composed of casing, 4" Block insulation, 3" Insulating Brick, 4-1/2" Fire Brick and 4-1/2" High Alumina Brick

18. Walls - Grate Abrasion Area

16" walls composed of Casing, 3/8" Asbestos sheet, 3" Block insulation, 3" Insulating Brick and 9-1/2" Silicon Carbide Brick

19. Primary (Under Fire) Air Systems (4)

60^o Air from refuse loading area

5 zone distribution under grates

Fans - 40,000 CFM, 10-1/4" H_2O static pressure
100 HP, 1200 RPM

20. Secondary (Overfire) Air Systems (4)

60^o F. air from refuse loading area

Complete combustion of furnace gases and control furnace temperature

Fans - 14,000 CFM, 20" H_2O static pressure
60 HP, 1800 RPM

21. <u>Induced Draft Fans (4)</u>

113,500 CFM, 6-1/2" static pressure

Motor	200 HP
Fan Speed	622 RPM
Design Temperature	550° F.

22. <u>Electrostatic Precipitators (4)</u>

Max. Capacity	100,000 CFM at 550° F.
Pressure Loss	0.5" H_2O
Gas Speed	Approx. 4 ft./sec.
Max. Outlet Concentration	0.2 lb./1000 lb. dry gas at 50 E.A.
Treatment Time	Approx. 5 sec.
Gas Weight	230,000 lb./hour
2 x 24 Collector Plates	9' x 24' high per Unit
70 KVP, 750 MA	

23. <u>Auxiliary Oil Burners (3)</u>

Bunker 'C' Oil	Approx. 5,500 lb./hr. at capacity
Steam generation	81,000 lb./hr. max., 680 psi, 545° F.
Motor & Fan	1750 RPM, 30 HP, 23,000 CFM
Oil Pressure	130 psi at Burner
Air	60° F. from refuse loading area

24. Stack (1)

Metal Clad, 3" Refractory Lined

Inside Diameter	12'
Total Height from Ground Elevation	184' (Stack 105')
Exit Gas (4 Units)	64 fps at 480° F.; 15,320 lb./min.

25. Boiler Tube Cleaning Systems (4)

Motorized rotating hammers and striker pins

80 strikers per Unit

3 assemblies/Unit driven by 2 HP Motors reduced to 3 RPM

26. Riddling Conveyors (4)

Horizontal water filled trough, basalt lined with scrapers. Collects clinker from the 5 chutes below grates.

1.5 HP drive system

27. Clinker Conveyors (4)

Inclined water filled channel, basalt lined with scrapers. Collects clinker from the water cooled clinker chute and from the riddling conveyor

2 Speed - 3.5/7.5 HP

28. Chain Cleaning Systems (4)

Air blower and nozzles cleans clinker conveyor scrapping chain.

29. Ash Pit (1)

Capacity	1,327 cu. yds. (Approx. 3 days storage)
	17-1/2' x 136-1/2' x 15' deep

30. Ash Pit Crane (1)

Rated Capacity	6 Tons (empty bucket 3.3 Tons)
Bucket Capacity	2-1/2 cu.yds.
Clinker	75 lb./cu.ft.
Hoisting	25 HP, 1200 RPM, 79 FPM
Trolley	3 HP, 1200 RPM, 100 FPM
Gantry	15 HP, 1200 RPM, 250 FPM

31. Fly Ash System

Mechanical enclosed conveyors collect fly ash from economizer hoppers and precipitator hoppers

Transported to exterior silo continuously

Capacity	306 Tons (fly ash 40 lb./cu.ft.) OR Approx. 2-1/2 days storage

32. Stand-by Power Supply

Diesel Generator Set (1)

300 KW, 575 V, 1800 RPM

33. Compressed Air

Compressors (3)	Single Stage, 360 CFM at 100 psi
Receivers (2)	Service air, 48" dia. x 44" h.
	Instrument air, 36" dia. x 96" h.
Air Dryer	300 CFM at 110 psi and 85^{0} F. drying to -40^{0} F. dew point

34. Make-Up Water Demineralizer System

City Water	30^{o} - 70^{o} F., 50 psi
3 ion Exchanger Sets	150 USGPM each, one regeneration
Capacity	300 USGPM
Ion Exchange Tanks(6)	- 4'-6" dia. x 5' h.
Caustic Reservoir (1)	- 8' dia. x 5' h.
Acid Reservoir (1)	- 8' dia. x 5' h.

35. Condensate Polisher

Min. 50% condensate return from Anglo

Condensate	300 USGPM at 170^{o} .

Ion Exchange to remove solids (softener)

2 Tanks	5' dia. x 5' h.

36. Condensate Storage

Capacity	10,000 US Gals., 15 minute reserve
Stainless Steel	12' dia. x 15' h.

37. Feedwater Heating & Degassing

Accumulator/Deaerator/Storage Tank

Operating pressure	40 psig
Water In	100^{o} - 160^{o} F.
Water Out	287^{o} F.
Flow	10,000 lb./hr. to 586,000 lb./hr. (deaerator)

The accumulator uses steam "peaks" to heat the feed water

Approx.	8' dia. x 40' h.

38. <u>Feedwater Pumps (3)</u>

2 - driven by 300 HP Motors

1 - driven by steam turbine (standby-power failure)

1000 psi (2300 ft. H_2O head)

39. <u>Boiler Heating System</u>

During shutdown periods, boilers are maintained warm by injecting steam through nozzles in the lower headers.

Permits quicker start-ups.

40. <u>Blowdown Tanks</u> 4' dia. x 6' H. (Continuous)

5' dia. x 6' H. (Intermittent)

B.L. Borovskis

March 24, 1975

BLB:rb

-- PROCESSED REFUSE --
A SALVAGE FUEL FOR EXISTING BOILERS

HERBERT I. HOLLANDER

ABSTRACT

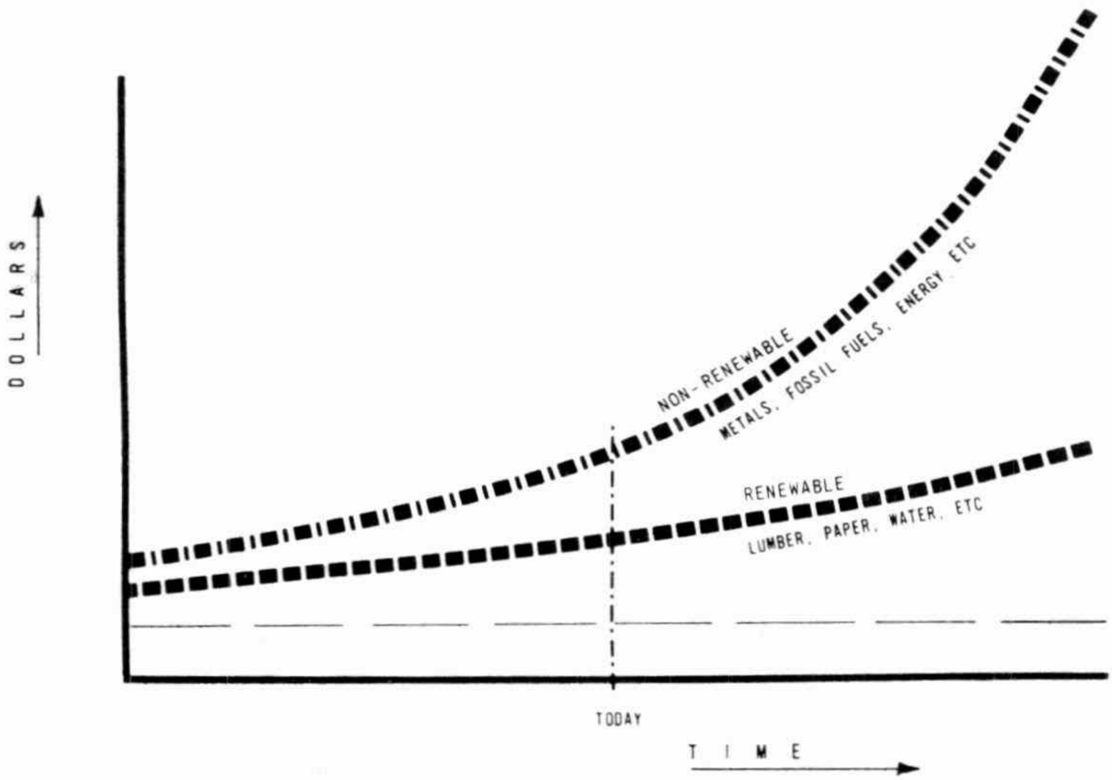
This discussion will endeavor to place into perspective the potentialities and some fundamental concerns in utilizing processed refuse as an on-going, low sulfur, local source of fuel. This emerging, locally derived, fuel source is becoming available in several prepared forms which could be suitable for many existing steam generators with only modest modification required. The thermochemical characteristics are compared with those of typical coals and several production wastes which have been used as salvage fuels. Some of the pertinent application parameters will be discussed and associated operation, performance and management considerations. This application review will be essentially confined to existing boiler installations and only the use of "prepared" solid fuels derived from refuse.

INTRODUCTION

With the new awarenesss and expressed concern regarding our environment, along with the "startling" realization that our minerals, energy and land resources are not inexhaustible, much recent rhetoric and print have been devoted to exploitation of the Communities' solid wastes for its resource values and also thereby diminishing the perplexing burden of waste disposal.

Solid wastes can be viewed as being comprised of two basic resource components: those considered renewable and those considered non-renewable. The renewable component being essentially cellulosic and the non-renewable components being minerals and energy. As the non-renewable resources approach depletion their value will increase at an accelerating rate.

FIGURE 1 - RESOURCE VALUE PROJECTION



Forestation and tree farming have become a very sophisticated technology. It has been reported by the American Forest Institute that the USA now is growing the equivalent of more than 75% of the usable timber which the Pilgrims may have found when they landed; and today's timberlands are of a much superior variety. It is now possible to grow a forest in 15-30 years. Tree farming can also be viewed as growing "energy plantations"; drawing upon natures way of converting solar energy into a form which can be expeditiously used by man directly or transformed into specific forms to suit specific needs. We cannot "grow" a coal seam or an oil field - - at all.

SOLID WASTE AS FUEL - WHAT IS IT?

Any view of municipal solid waste - - as discarded - - would discourage a second glance - - no less prompt involvement. However, even cursory investigation of the constituent make-up and the basic thermochemical analysis do reveal significant fuel resource potentialities and some material resource values. Typical as-discarded mixed municipal refuse composition is shown in Table I with projected composition through 1990. Although this provides average values it should be recognized that the constituent make-up can vary widely from season to season and even day to day. However, if they were processed to remove much of the metals and ceramics (glass) as well as result in a reduction in moisture the variability of the remaining organic fraction would be moderated and its potential value as a fuel significantly enhanced.

TABLE I - MUNICIPAL WASTE COMPOSITION*

	Typical Northeast USA	Projected Composition			Trend
	1968	1975	1980	1990	
FOOD WASTES	21.1	17.9	16.2	14.0	↙
PAPER PRODUCTS (NEWSPAPER ± 12%)	38.2	40.8	41.5	45.0	↗
YARD WASTES	14.1	13.2	12.9	12.2	↙
METALS	8.7	9.0	9.4	9.0	↗
GLASS	8.8	9.9	10.3	9.5	↗
WOOD	2.7	2.2	2.0	1.6	↙
TEXTILES	2.0	2.1	2.1	2.5	↗
LEATHER, RUBBER	1.5	1.5	1.5	1.5	
PLASTICS	1.1	1.9	2.8	3.5	↗
MISCELLANEOUS	1.8	1.5	1.4	1.2	↙
Moisture	25.9	23.4	22.1	20.5	↙
Total Ash	21.8	22.9	23.5	22.4	↙
HHV-BTU/pound-af	4,582	4,719	4,811	5,040	↗
HHV-kilojoule/kg-af	10,880	10,990	11,210	11,740	

*Percent as Discarded

Source: DHEW-NAPCA Contract CPA 22-69-23

Moisture	15.9	13.4	12.1	10.5
Ash (less metals, glass)	5.5	5.3	5.2	5.2
HHV-BTU/pound-af	6,760	7,000	7,100	7,250
HHV-kilojoule/kg-af	15,750	16,310	16,540	16,890

The data extrapolations shown on the bottom rows of Table I project the possible values of the fuel fraction refined from the as-discarded municipal wastes.

The sulfur content and calorific value of the refuse constituents are shown in Table II.

TABLE II - SULFUR AND HHV

SULFUR AND CALORIFIC VALUE OF CONSTITUENTS IN SOLID WASTES

	Sulfur wt %	KiloJoule/kg Dry	Btu/lb Dry
METAL	0.01	1,720	740
PAPER PRODUCTS	0.12	16,310-18,640	7,000-8,000
PLASTICS	0.07-0.55	25,630-41,940	11,000-18,000
LEATHER/RUBBER	0.40-1.30	23,300-37,280	10,000-16,000
TEXTILES	0.2	18,640	8,000
WOOD	0.11	18,640-20,970	8,000-9,000
FOOD WASTES	0.25	18,640-20,970	8,000-9,000
GLASS	0	152	65
YARD WASTES	0.35	15,145-17,475	6,500-7,500

SALVAGE FUEL - THERMOCHEMICAL CHARACTERISTICS

Volatile Matter

Although an Ultimate Analysis does provide the basic information for stochiometric determinations, it is the proximate analysis, particularly the Volatile Matter which provides some indication of combustion performance in the furnace. Table III provides representative analyses for a broad range of waste materials that have been utilized as salvage fuels separately or in combination with conventional fuels.

TABLE III - WASTE FUELS - PROXIMATE ANALYSIS

	M	VM	FC	A	S	Btu - Dry - kJ/kg	
PEANUT HUSKS	5.5	68.4	24.9	1.2	0.1	8,467	19,730
RICE HULLS	8.2	64.3	13.2	22.5	0.1	6,260	14,590
FURFURAL RESIDUE	(55)	70.8	23.2	6.0	0.4	8,600	20,040
COFFEE	(70)	80.2	19.4	0.4	0.2	11,420	26,610
WOOD - PINE BARK	(50)	73	24.2	2.8	0.1	9,030	21,040
GREEN FIR	45	45	9	0.7	0.06	4,910	11,440
SEASONED	24	65.5	9.5	1.0	0.08	6,300	14,680
KILN DRIED	8	79.2	11.5	1.3	1.0	7,630	17,780
CORRUGATED BOARD	8	75	13	5	0.2	7,600	17,710
TIRES (Granulated)							
TREAD RUBBER	0.9	66.5	29.2	3.4	1.04	16,287	37,950
COMPOSITE FIBRE	2.8	80.0	15.3	1.9	1.04	11,846	27,600

Similar information and a constituent mix of general industrial plant waste (trash) is shown in Table IV.

TABLE IV - GENERAL INDUSTRIAL PLANT WASTE

	Weight Percent	Moisture	Volatile Matter	Sulfur	Inerts	HHV - dry kJ/kg	HHV - dry Btu/lb	Ash Fusion Temp* °C	Ash Fusion Temp* °F
CORRUGATED BOARD AND MISC. PAPER	52	8	75	0.2	5.0	17,710	7,600	1,220	2,230
HARDWOOD (Crates, Pallets, etc.)	28	12	67	0.1	3.0	19,340	8,300	1,480	2,700
TEXTILES	5	10	80	0.2	3.0	18,640	8,000	1,190	2,180
PLASTICS (Film and Rigid)	4	1	95	0.1	1.5	34,000	14,600	-	-
METALS	3	2	-	0.1	95.0	280	120	-	-
MISCELLANEOUS RUBBER	2	2	83	2.0	15.0	26,330	11,300	1,230	2,240
FOOD WASTES	1	50	20	0.5	5.0	19,570	8,400	1,170	2,140
SWEEPINGS	5	25	54	0.2	20.0	13,980	6,000	1,210	2,200
COMPOSITE WEIGHTED ANALYSIS		10	70	0.2	8.0	18,170	7,800		

COLORIFIC VALUE (HHV) ADJUSTED TO REFLECT COMPOSITE (10%) MOISTURE = 16,540 kJ/kg (7,100 Btu/lb.)

*Softening temperature in oxidizing atmosphere

NOTES:

The glass constituent in general plant waste is expected to be less than 1%.

The solid waste constituent mix and their discrete characteristics will vary from plant to plant in the same industry and probably even within the same company.

For relative comparison of these values with a spectrum of U.S. Coals, refer to Table V. Of particular significance is the variation in Volatile Matter.

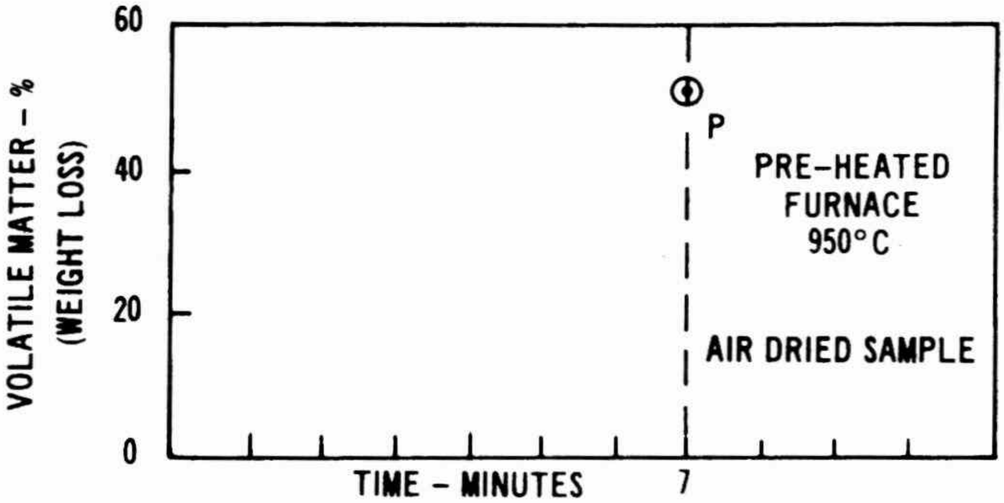
TABLE V - U.S. COALS - PROXIMATE ANALYSIS

		*M	VM	FC	A	S	Btu - Dry	kJ/kg
ANTHRACITE		2.5	6.2	79.4	11.9	0.6	12,925	30,115
BITUMINOUS	- W. VA.	1.0	18.6	77.3	5.1	0.7	14,715	34,290
	- PENNA.	1.5	23.4	64.9	10.2	2.2	13,800	32,150
	- PENNA.	1.5	30.7	56.6	11.2	1.8	13,325	31,050
	- KY.	2.5	36.7	57.5	3.3	0.7	14,480	33,740
	- OHIO	3.6	40.0	47.3	9.1	4.0	12,850	29,940
	- ILLINOIS	12.2	38.8	40.0	9.0	3.2	11,340	26,420
LIGNITE	- N.D.	37.0	26.6	32 2	4.2	0.4	7,255	16,900

*Bed Moisture

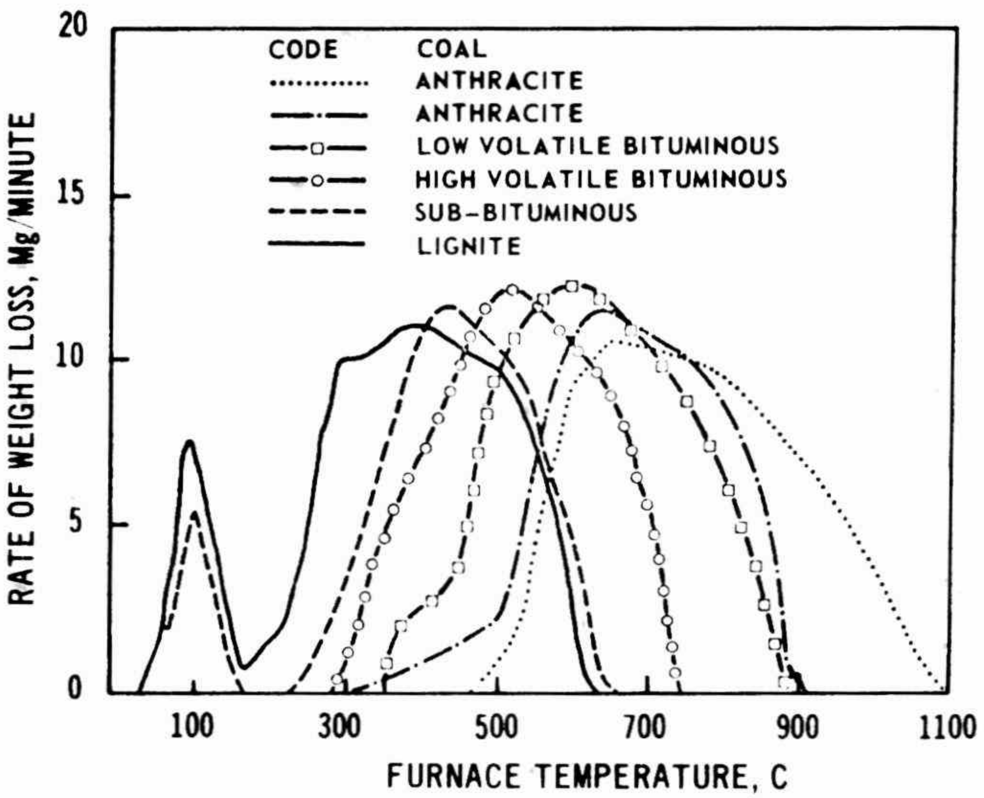
The fuels salvaged from wastes almost invariably have significantly higher Volatile Matter (VM). The empirical VM determination is intended to reveal the gaseous character of the fuel as an indication of its reactivity in a furnace. The traditional procedure is to determine the weight loss of a carefully prepared (dried) 1 gram sample which has been subjected to 950°C for seven minutes in a muffle furnace (Figure 2).

FIGURE 2 - VOLATILE MATTER PLOT



This procedure developed at the turn of the century and the library of data on coals accumulated since then, has been a basic reference particularly for the low and high rank bituminous coals. However, in recent years more graphic representation has been necessary to provide a spectrum of reactivity for a broader range of fuels. Figure 3 is illustrative of the type of data which is now being accumulated.[1]

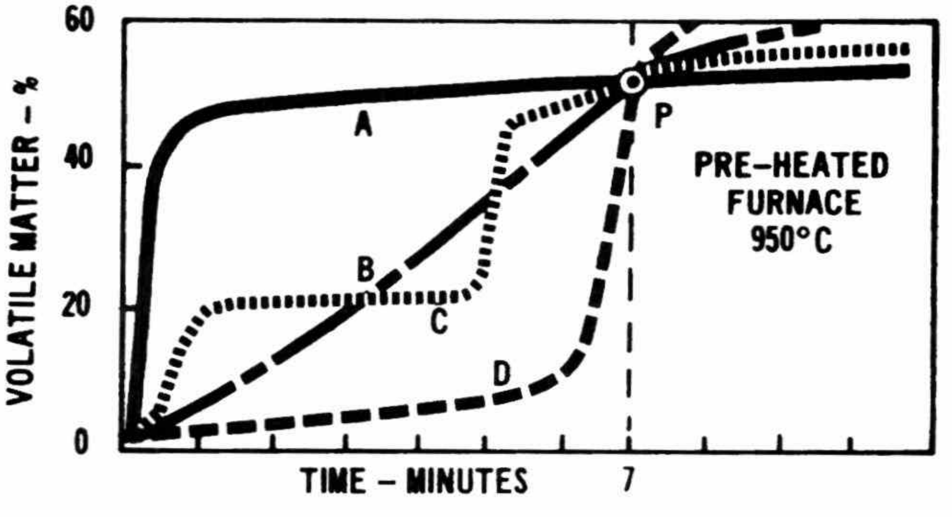
FIGURE 3 - BURNING PROFILES



The VM determinations on the various salvage fuels shown in Table III and Table IV were made using the prescribed Bureau of Mines 638 (ASTM D-3175) procedures. Almost invariably these values are well beyond the range of that found in most coals.

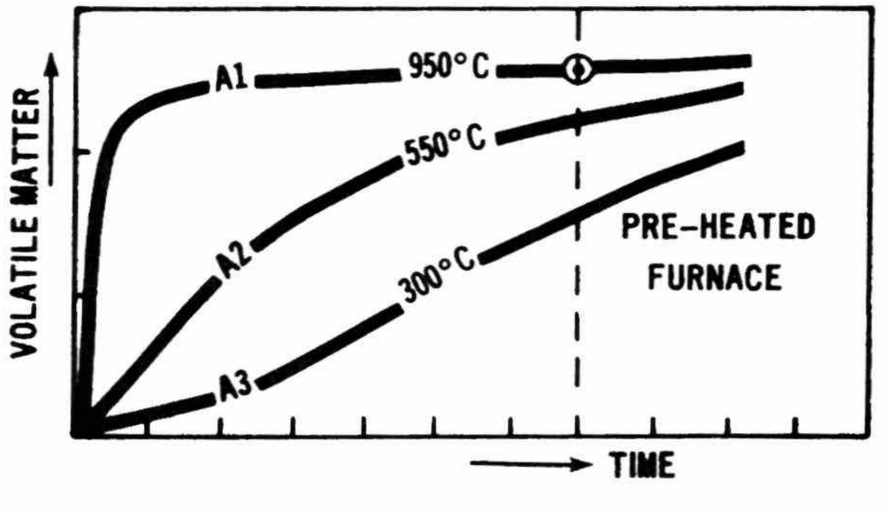
The time required for pyrolysis (Volatilization) is also an indication of the potential rate of reaction or heat release.[2] Figure 4 is intended to represent the conceivable time related profiles of volatilization which might occur. Obviously the rate of reaction would be quite different for Profile A as compared to Profile D, although the standard analytical procedures would report the same Volatile Matter value for each.

FIGURE 4 - HYPOTHETICAL VM PROFILES



Even more revealing would be a family of plots indicating Volatile Matter versus time at prescribed temperature levels as presented in Figure 5.

FIGURE 5 - TIME/TEMPERATURE PROFILES



These profiles would indicate the rate of volatile energy release (potential reaction intensity) and in addition the conventional Volatile Matter value in the fuel for association with the traditional procedures, accumulated data and performance history.

However, this is still only indicative of what might occur in a furnace since for reproducibility the analytical procedure must of necessity be under closely controlled conditions in a fuels laboratory, using only a "representative" DRY 1 gram sample, powered to pass a No. 60 sieve (openings 250 µm or 0.0098 in.^{2}).

Therefore, the analysis information would still only be a guide and should be correlated with actual field burning trials and trained observation to establish projectable relationships.

Furnace configurations designed for low volatile, slower reacting fuels may not readily accommodate significant quantities of the "gassy," highly reactive nature of salvage fuels with their long flame characteristics. Yet, in perhaps the right fuel mix proportions they may expedite the combustion of the slower reacting coals without detrimental furnace effect.

Refuse Derived Fuels (RDF) burned alone or in combination with fossil fuels are best suited for open furnaces with long flame travel and usually do not require refractory surfaces for reradiation to stimulate the combustion reaction. However, the reactivity of many fuels can be inhibited by moisture, size consist or form, ash content and the extent of entrained inerts.

Ash Fusion Temperature

An area of concern to the fuel user would be the slagging or clinkering potential of the ash. Since the constituent mix of solid waste will vary, an examination of some basic characteristics of the discrete constitutents can be informative. Review of Table VI provides ash fusion temperature values of the combustible residues and the non-combustible constitutents commonly found in solid wastes. With the exception of the glass fraction, the remaining components have ash fusion values within the range commonly encountered with most coals. The refined fuels derived from refuse would have much of the ceramics and metals removed.

TABLE VI - ASH FUSION TEMPERATURES

"Laboratory" Determination of ASTM Fusion
Temperature of Residue Constituents
and Melting Points of Pure Metals

	Initial Deformation		Softening		Fluid	
	°C	°F	°C	°F	°C	°F
Clear Glass	805	1480	916	1680	1005	1840
Brown Glass	882	1620	949	1740	1138	2080
Green Glass	893	1640	982	1800	1138	2080
Ash from:						
Garbage	1105	2020	1172	2140	1205	2200
Cardboard, Corrugated	1127	2060	1183	2160	1227	2240
Misc. Paper	1183	2160	1261	2300	1361	2480
Grass and Dirt	1138	2080	1227	2240	1272	2320
Textiles	1116	2040	1194	2180	1227	2240
Heavy Plastics, Leather, Rubber	1150	2100	1216	2220	1261	2300
Bones and Shells	1539	2800	1539	2800	1539	2800

	Melting Points	
	°C	°F
Iron	1536	2795
Iron Oxide (Fe_2O_3)	1563	2849
Aluminum	649	1200
Aluminum Oxide (Al_2O_3)	2045	3713
Lead	328	622
Tin	232	449
Zinc	409	769
Lime (CaO)	2562	4676
Silicon Oxide (SiO_2)	1611	2930

SOURCE: ASME National Incinerator Conference
1968 Proceedings, Page 140.

These temperatures were determined with the laboratory furnace having an oxidizing atmosphere. The temperatures could be somewhat lower in an oxygen deficient (reducing) atmosphere.

Note that these analyses were made in an oxidizing atmosphere. Based on the experience with coal ash, somewhat lower values in a reducing atmosphere could be anticipated. These data also do not reveal possible synergism and shifting of eutectic when the components are in various combinations. However, referring to the relative percentages of each constituent in the fuel (Table 1) aids in placing possible concerns in more meaningful perspective. The synergistic aspect of ash fusion temperature can also become a factor when utilizing this salvage fuel supplementary with coal or oil. Of course the real significance of this aspect on furnace performance is, a function of: - type of firing (mass, semi-suspension, full suspension) - type of firing equipment - type and character of fossil fuel being burned - ratio of fossil fuel to salvage fuel to be utilized - relative fuel size consist - extent of waterwall coverage - heat release - furnace liberation - flame travel - furnace exit temperature, excess air, furnace turbulence, etc.

Salvage Fuel - Sizing

Most wastes resulting from industrial production are of relatively uniform size and of reasonably predictable nature. However, general plant wastes and some production wastes do require controlled size reduction to make them suitable as a fuel and facilitate handling, storage and retrieval. The performance of any fuel burning system is materially enhanced if the fuels can be processed to make them reliably predictable in regard to their physical and chemical properties.

Entrained moisture is the most significant element influencing combustion and energy recovery efficiency. However, there are practical and economic limits in attaining moisture reduction. In specific circumstances many cellulosic base materials can be consumed as a fuel with moisture levels as high as 50% without requiring support fuel.

Reduction of wastes, if not complete avoidance, is an understandable goal of management. However, actual attainment can only be approached, although many wastes of yesterday are by-products or prime products of today.

Many industries who have previously only looked upon the use of their wastes for fuel as an expedient disposal method have recently come to regard their wastes as a reliable (and valuable) local energy resource ..., even as a by-product of production.

Some of the wastes which have long been used as fuels for steam generation are indicated in Table VII.

TABLE VII - WASTES AS FUELS

WASTES USED AS FUELS FOR STEAM GENERATION

BAGASSE	PINE BARK & SHAVINGS
BARK	HARDWOOD BARK & SHAVINGS
COCONUT SHELLS	RICE HULLS
COFFEE GROUNDS	ROOFING PLANT BROKE
CORN COBS	RUBBER PRODUCT WASTE
COTTON SEED HULLS	SLUDGES
COW DUNG	SPENT SOLVENTS & LUBRICANTS
FIBRE CAKE	SPENT SULPHITE LIQUOR
FLAKEBOARD BROKE & DUST	TAN BARK
FURFURAL RESIDUE	TARS
MUNICIPAL REFUSE	WASTE OILS
PEANUT SHELLS	WOOD FLOUR
FLOORING (LINOLEUM-VINYL) REJECTS	

In regard to municipal solid wastes as a source of "processed" fuel (Refuse Derived Fuel), its varying heterogentic character would necessitate greater refinement than most industrial wastes. One or more stages of size reduction may be necessary with suitable classification/separation processes. This effort tends to provide physical and chemical hemogeneity, dispersal and even reduction in moisture, and facilitates effective removal of extraneous non-combustibles including metals and ceramics which may have potential "material" resource value, in lieu of negatively effecting the realizable fuel value.

Refuse Derived Fuels (RDF) for use directly in furnaces of existing boiler installations could be available in the following general forms:

... sized to pass coarse screening 30 cm (12") square openings
... sized to pass screening with 10 cm (4") square openings
... sized to pass screening with 2.5 cm (1") square openings
... powered to pass screening with 100 mesh opening

The screen sizes shown are only representative. The intermediate and smaller size screen "refined" products can be formed into lump fuels:

— Cubettes - about the size of ice cubes - 3.8 cm x 3.8 cm x 5 cm (1-1/2" x 1-1/2" x 2")
— Pellets - cylindrical, approximately 1 cm (3/8") dia. x 2.5 cm (1") long

RDF refined into a powder could be formed into - "Briquettes" approximately 3.8 cm (1-1/2") square. These cellulosic "lump" fuel forms are of higher bulk density, are not spongy, can be handled more nearly like a granular material and embody reasonable structural integrity.

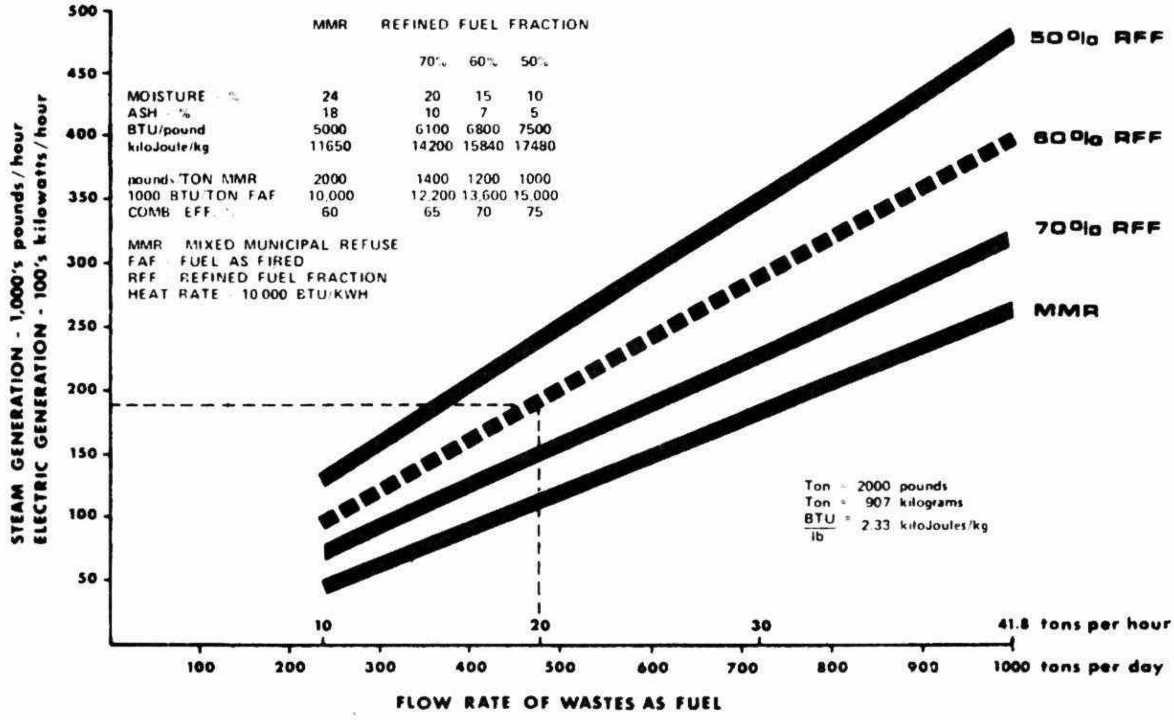
Obviously all of these fuels must be weather protected to retain their physical structure and maximize utilization of their energy value.

As with coal preparation, it would seem appropriate that the degree of refinement of salvage fuels should be limited to only that required for practical, economic utilization in each particular fuel using system.

The potential steam or electric generation which may be possible, utilizing Refuse Derived Fuels of various degrees of refinement is illustrated in Figure 6. Please note that a combustion efficiency was selected for each plot to correspond with the degree of fuel refinement.

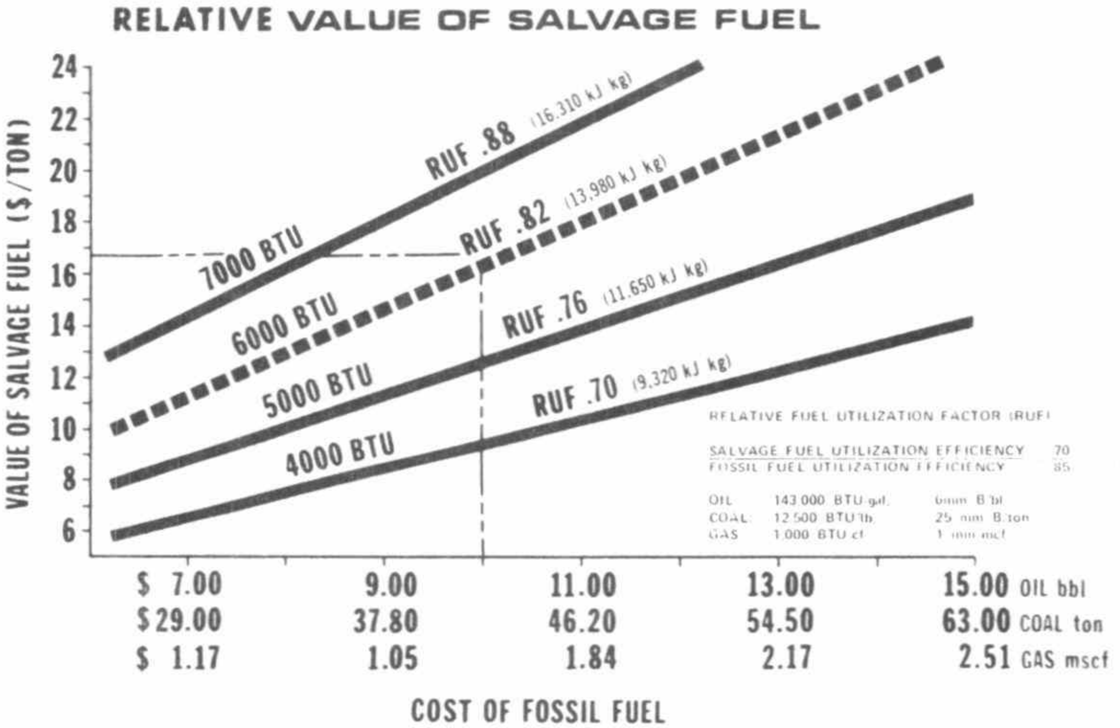
FIGURE 6

POTENTIAL STEAM / ELECTRIC GENERATION WITH WASTES AS FUEL



The plots of relative value of salvage fuel to conventional fuels as shown in Figure 7 endeavors to account for "relative fuel utilization efficiency" so that the values would be on an equivalent net BTU basis. Other cost factors for utilization of these fuels were not included since they were considered to be specific to each particular plant and local circumstances. However, these plots do reveal some of the economic potentialities and can assist in determining whether further investigation is warranted.

FIGURE 7



Some Basic Application Considerations

Although drawing upon the operational experience of hundreds of waste fuel fired boiler installations can be valuable it must be recognized that most of these were originally designed for the fuels being fired. As yet there are few RDF fired installations which have logged extensive operating hours. There are very few existing installations which were adapted to utilize RDF. Those that have been or are being currently adapted will be utilizing finely shredded-classified RDF. From the foregoing discussion it is apparent that some tailoring of RDF can be provided to suit the type of boiler plant installation.

Although actual adaptations or new additions to a boiler plant facility will not take place until there are realistic projections of when RDF will become generally available, it may become necessary to commit sincere intention to do so, thereby providing an essential element for the viable undertaking of a suitable waste/fuel processing facility.

A "cooperative relationship" with mutual understanding is essential between the fuel user and the fuel processor if a beneficial arrangement is to be developed and maintained. The fuel processing facility must reasonably accommodate the basic fuel quality and quantity requirements of the fuel user who in turn must accommodate reasonable variability in the fuel product received.

Some of the possibilities and considerations which should be addressed regarding existing boiler installations and the probable type of RDF most suitable would be appropriate at this point. The boiler unit, ancilliary equipment and general configuration of systems designed for bituminous coal, lignite or wood waste firing can most readily accommodate these Refuse Derived Fuels in one form or another. However, there are industrial boiler-furnace systems designed basically for fuel oil firing which are successfully burning suitably prepared waste fuels which are essentially free of inerts and low in moisture.[3] These units were originally designed for these fuels.

The "mass burning" lump coal fired furnaces should be capable of burning a mix of formed RDF as cubettes, pellets or briquettes, with bituminous coal. The gate fed travelling (chain) grate stokers or the multiple retort underfeed stoker systems should be capable of accommodating RDF as a significant percentage of their fuel requirements. However, the actual ratio of RDF to coal depends on many factors such as coal characteristics, loads to be carried, available grate area, stoker feeding capacity, flame travel, furnace water cooling, fuel handling, storage and retrieval, etc. However, burning trials at an electric generating plant on a multiple retort stoker fired boiler (150,000 pph) with a 3:1 mix of Kentucky coal to RDF cubettes had indicated that the fuel bed became more free burning, had less tendency to form coke trees and developed smaller, less dense clinkers.[4]

Nevertheless, it should be recognized that although beneficiated salvage fuel may be supplied in lump form, when compared to coal it is still significantly lower in heating value and specific density. Therefore, perhaps three to four times the volume of this fuel must be fired for the energy equivalent of coal. Considerations which may be necessary are; adequacy of grate area for the volume of fuel which can be handled and still provide good burnout, adequacy of fuel feed mechanisms which are usually volumetric, adequacy of fuel handling and storage, and provisions required for fuel blending.

Relative fuel quantity determinations become more apparent when comparisons are made on the basis of "equivalent" million BTU. This analayis should also factor in the anticipated "relative fuel utilization efficiency". A major influence will probably be the difference in total moisture in the fuels to be fired.

Although probable ratios of salvage fuel to fossil fuel may be projected by reviewing the various factors and constraints, the practical operating ratio will finally be determined by actual burning trials; the usual procedure used in the final analysis in determining the suitability and performance of a new coal source. Nevertheless, analyses and projections are necessary so that system requirements for fuel handling and controls can be anticipated and adequately provided for.

As with coal, semi-suspension (spreader) firing systems which normally operate with a thin fuel bed on the grate, a broad range in salvage fuel quality, relative quantity and fuel size can be accommodated. Salvage fuel sized to pass 4" square screening should

be completely adequate although some coarser material could also be tolerated if it can be delivered to the furnace feeders. The lump RDF could probably be mixed and fed into the furnace with coal through the conventional mechanical feeder-distributors, but bear in mind these are volumetric mechanisms. The ratio of the RDF to coal may be limited by the volumetric feeding capacity of the feeder-spreaders. The mechanical impact of the feeder-distributor blades will reduce the RDF lump size to some degree which would be considered desirable since it would facilitate longitudinal fuel distribution on the grate.

If the furnace configuration is suitable, fuel distributors could be installed to feed RDF (in one of its forms), separately from coal (or oil) which is quite common with industrial waste firing.

Full suspension firing of salvage fuel would require sizing to 2.5 cm (1") and preferably smaller. This probably will entail several stages of size reduction of the "as-discarded" waste and thereby readily permit removal of metals, ceramics, etc., between intermediate stages. This degree of fuel processing should provide a refined fuel of more consistent physical and thermochemical properties. This "finer sized" RDF could be handled and burned, as is or formed into "pellets" or refined further into a "powder" for direct firing or formed into "powder briquettes."

When compared to sized RDF, the pellet or briquette formed fuel with its higher specific density and structural integrity, should provide greater ease of transport, handling, storage, retrieval and blending. These advantages may justify the additional costs for the forming equipment systems, the associated operating and maintenance cost and the energy expended.

However, for full suspension firing these formed salvage fuels would require pulverization. Since the constitutents of the pellets are fibrous in nature, they are resilient and less friable than most bituminous coals and may require a longer grind to size, impose a capacity burden on the existing P.C. mills, may effect mill classifier performance, require relatively more mill power and possibly more maintenance for the equivalent BTU available from coal. These considerations would apply to a lesser degree to briquettes formed from powdered RDF. Another area which may become a real concern relates to the significantly higher Volatile Matter when compared to coal, particularly when P.C. Mills are swept with "hot" air.

Although many of the areas previously discussed also apply to boiler - - furnace systems designed for low volatile coals (including Anthracite) these systems present some unique considerations. The mass burning grate fired systems are usually equipped with high furnaces having long rear furnace arches usually covered with refractory and located quite low, close to the fuel bed, with a relatively narrow throat leading to the upper furnace. Although the arch can effect improved bed burnout, the rapidly burning volatiles from RDF at the nose of the arch make make it vulnerable to high heat flux, washing, or slag build-up. On the other hand, the vigorous combustion immediately above the bed forward of the arch should assist in expediting the ignition and combustion of the slow burning coal. The high furnace above the arch would provide ample flame travel to consume the volatile gases before they enter the convection bank.

The suspension fired anthracite type furnaces would also provide ample furnace retention time. However, large expanses of refractory walls would be subjected to higher heat flux resulting from rapid combustion of the volatile rich salvage fuels. This may be beneficial in expediting coal burning especially at the lower boiler loads but could result in some slag deposition.

There may be particular circumstances where extensive running trials would be desirable with a rigorous evaluation program so that those furnace performance factors mentioned (among others) can be identified and assessed for their significance and suitable provisions made to utilize this "new" energy source on a continuing basis. There are options and trade-offs to be explored so that the system most amenable to all entities involved will ultimately be incorporated.

CONCLUSIONS/SUMMARY

The objective of this discussion was to be comprehensive in covering those concerns considered as basic in determining the nature and type of Refuse Derived Fuel which might be accommodated in existing types of boiler system installations. There are additional significant areas to be considered, which will be the subject of a sequel to this presentation. It should be apparent that most considerations are very "site-specific" and this review was only intended to provide an indication of some of the potentialities and basic concerns.

Most existing boiler plant installations originally designed to burn coal probably could accommodate some form of Refuse Derived Fuel either separately or in some finite combination with fossil fuel.

In general, the least complex system necessary to provide a Refuse Derived Fuel product having the physical and thermochemical quality consistent with the particular fuel user's equipment, mode of operation and performance requirements will result in:

- the greatest gross energy yield from the as-received waste materials
- the most reliable RDF supply
- the least salvage fuel cost

The concept to use wastes as fuel has probably been practiced in varying degrees since the time of Adam. It can be an on-going, local energy source which we can not ignore any longer. An array of techniques and systems are now available and new ones seem to be continually emerging, all seemingly ready for innovative application.

THE TIME TO PROCEED IS NOW.

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Key Words:

- Ash Fusion Temperature
- Firing Methods
  - Mass
  - Semi-Suspension
  - Full-Suspension
- Proximate Analysis
- Pulverization
- Pyrolysis
- Reaction Intensity
- Refined Fuel Fraction
- Refuse Derived Fuels
  - Formed Cubettes (d-RDF)
  - Formed Briquettes (d-RDF)
  - Formed Pellets (d-RDF)
  - Powder
  - Shredded - classified
- Volatile Matter
- Relative Fuel Utilization Efficiency

An Assessment of The Industrial Waste Management Industry in Ontario

F. W. Tricker

Last year in Ontario, some 400,000 tons of hazardous industrial waste required some form of off-site handling. These wastes are the result of the production of a variety of goods and services demanded by our affluent society. How much is 400,000 tons? It is enough to fill this auditorium 100 times, and the volume is increasing every year.

What is meant by hazardous industrial waste? Well, it is made up of liquids, solids, sludges, slurries, tars or residues. Some may be toxic, depending on the concentration of contaminants. They may contain carcinogens, teratogens or even mutagens.

The 400,000 tons per year estimate includes 40 to 50 million gallons of liquid industrial waste. The balance consists of solids, semi-solids and drums. It does not include the non-hazardous industrial wastes, such as paper and wood, nor does it include radioactive wastes.

Improperly handled, industrial wastes can cause serious pollution problems, and these problems tend to persist. Until recently (that is, the last 10 years), the disposal of industrial wastes received little attention. They were discharged into rivers, municipal sewer systems, open dumps and farmers' fields, or simply stored in open lagoons. The impact of inadequate disposal is now receiving a lot of attention. Government authorities and the public have become alarmed about the presence of the "phantom chemicals".

Improved monitoring techniques detected the presence of mercury pollution, followed by a better recognition of the serious health hazards posed by relatively small amounts of asbestos, lead, PCB's, Mirex, cadmium and a host of other chemical substances in the environment.

Once the seriousness of the problem had been identified, many industries in the province made maximum use of modern technology to improve the quality of their discharges to the air and water. This progress has been remarkable.

At the same time, it became evident that many industrial firms could not handle all of their own wastes. In addition, the installation of air and water pollution control facilities often resulted in the creation of concentrated waste streams requiring off-site disposal. This gave rise to a new industry which I refer to as the industrial waste management industry. Its function is to collect, transport and dispose of industrial wastes that cannot be handled economically by the generator of the waste.

The industrial waste management industry is young, small, and maturing rapidly. It consists of a large number of haulers and a handfull of approved treatment and disposal sites. Of the total revenues for the industry 70 per cent goes to transportation and 30 per cent to disposal. The market is small, relative to those in Europe and the United States. The technology is complicated by the variety and variability of waste streams.

Undoubtedly, the major problem today is a serious lack of technically and socially adequate treatment and disposal facilities. Landfill sites have become the predominant outlet for ultimate disposal of liquid industrial wastes. With tighter controls on discharges into the air and water, industry has turned to disposal on land. As older landfill sites are filled up, the pressures mount on the remaining sites. New sites are not being created, as it is recognized that they would not get approval to handle hazardous industrial wastes.

For example, the Beare Road landfill site, operated by Metro Toronto, has been accepting liquid industrial wastes for a number of years because there were no other alternatives available for these wastes. However, as the site nears its ultimate capacity the volume of solid waste available to soak up the liquids is dwindling and liquids will no longer be accepted after December 1978. The waste management industry will have to respond to this challenge of developing suitable outlets for these wastes. Otherwise, they will end up in a landfill site in some other community.

Landfill disposal of industrial wastes can result in the migration of hazardous substances into ground water. The extent of the migration and the impact of such contamination is difficult to assess, particularly since the contamination can occur over a long period of time. In some cases, landfill disposal may be the best alternative available. However, it

is clear that the disposal on land of toxic and hazardous industrial wastes is an unacceptable long-term solution to the problem.

But, if landfilling is undesirable, what alternatives do we have? Methods currently available in Ontario include incineration, deep well disposal and recycling.

Incineration is an excellent tool for detoxifying a wide range of waste products. Toxic organic compounds are thermally oxidized at high temperatures to yield harmless products of combustion. Two incinerators, located in Mississauga and Sarnia handle approximately 50 per cent of liquid wastes generated in the province. The main limitation of incineration is that waste products with high dissolved solids, mainly inorganic in nature, cannot be adequately incinerated because of the emission of particulates and toxic inorganic components.

Liquid wastes with high dissolved solids were previously handled by deep well disposal into the Detroit River Formation. The use of deep well disposal in this formation has been restricted over the past four years by government regulation. Currently, the only liquids handled in this manner are cavern washing brines. Deep well disposal of industrial waste into the Cambrian Formation is not prohibited by legislation, but to date no Cambrian facilities have been operated in Ontario, largely due to negative public reaction to proposals involving deep well disposal.

Recycling of waste products is limited to some specific waste streams such as waste pickle acids, spent refinery caustics and solvents.

Since the processes currently available cannot handle all wastes being generated, we continue to rely on land disposal, as the last alternative. Why has the waste management industry been unable to provide the necessary facilities. Is the problem one of technology, economics or politics?

Technology is available for the treatment and disposal of most industrial waste streams generated in the province. Some of the available methods are:

- Physical Treatment: filtration, evaporation carbon sorption, reverse osmosis

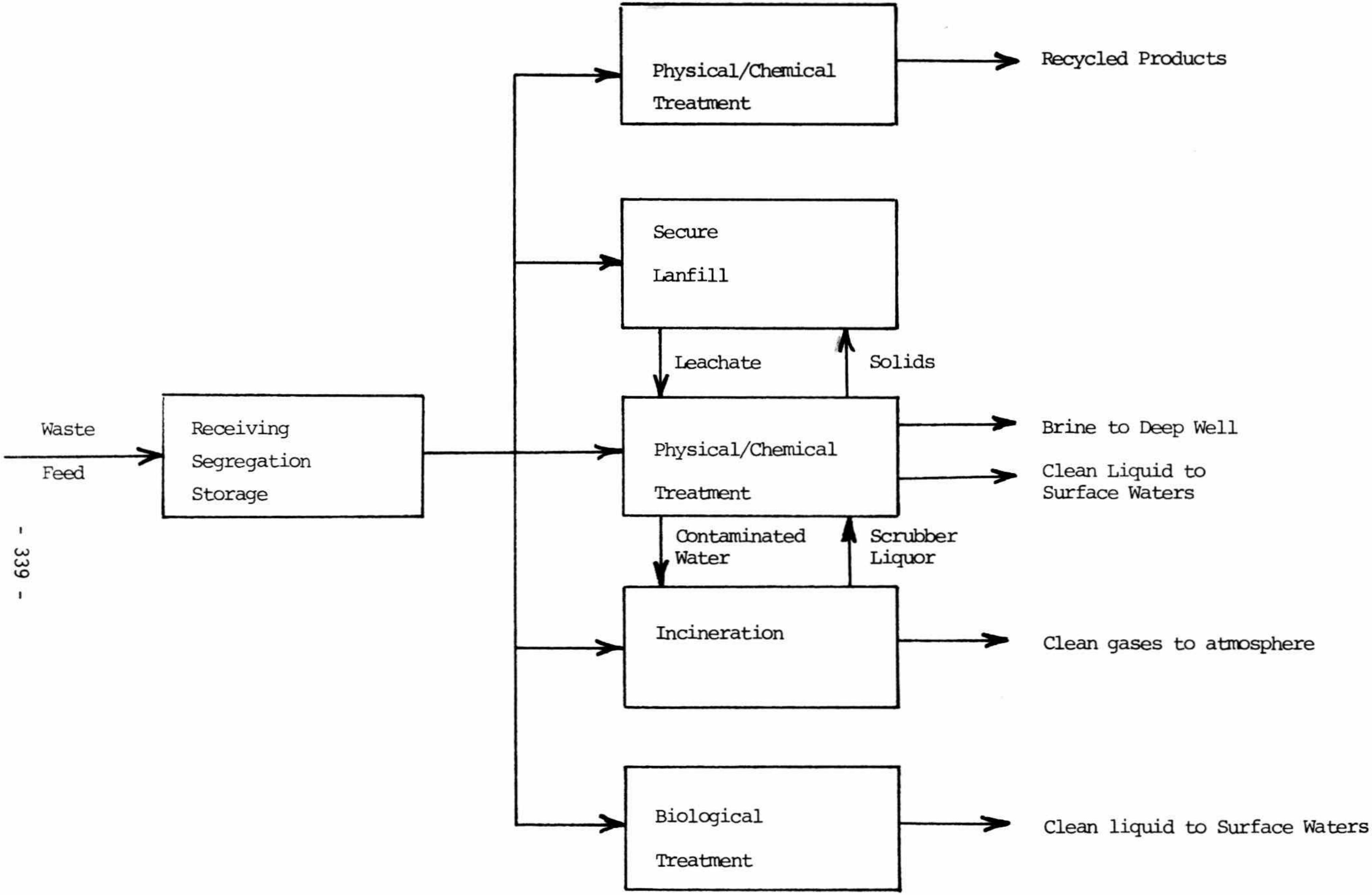
- Chemical Treatment: neutralization, oxidation-reduction, precipitation, ion exchange

- Thermal Treatment: incineration, pyrolysis

- Biological Treatment: activated sludge, aerated lagoons, oxidation ponds, trickling filters

- Ultimate Disposal: secure landfill, deep well.

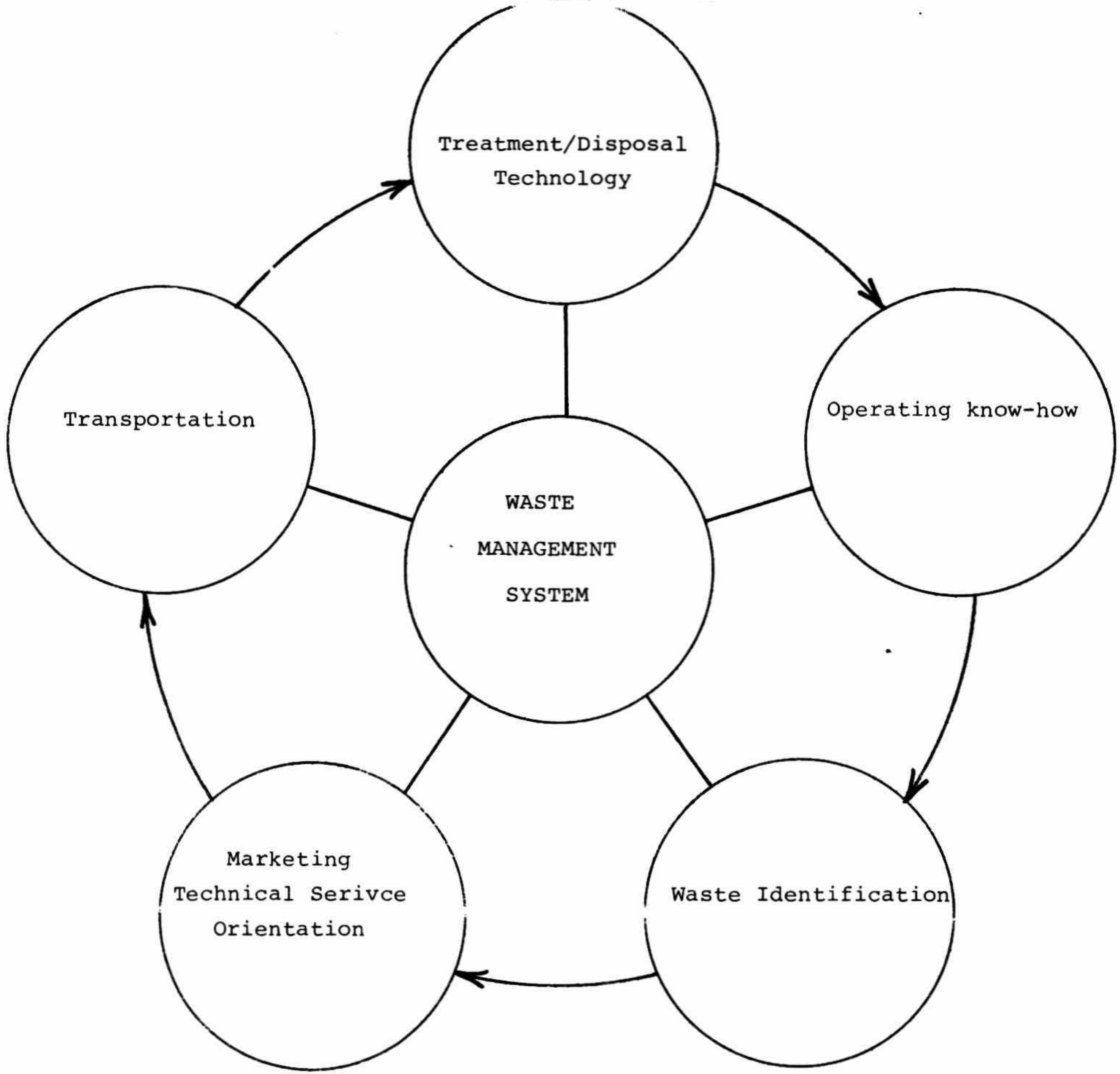
The variety of feed streams make it impossible to use a single process to handle all wastes adequately. There are no miracle processes that provide a simple solution. Series of processes must be utilized as depicted on the conceptual flow plan on the following page.



CENTRAL WASTE FACILITY FOR INDUSTRIAL WASTES

This conceptual diagram illustrates the systems approach to waste management. Clearly there is a high degree of interdependence among the unit processes employed. For example, a secure landfill site is dependent on a physical/chemical treatment system to detoxify hazardous wastes to the fullest extent possible. At the same time, leachate from this secure landfill site must be treated prior to discharge to the environment.

The operator of a comprehensive facility such as the one depicted has a number of options for handling any specific waste stream. He can therefore choose the best one for that stream in order to minimize the impact on the environment. A disposal site utilizing one unit process does not offer this flexibility and some compromises are likely to be made.


Treatment/Disposal
Technology
Operating know-how
Waste Identification
Marketing
Technical Serivce
Orientation
Transportation
WASTE
MANAGEMENT
SYSTEM

The system approach involves more than treatment and disposal technology. Operating know-how is a very important component of the technology, as anyone in the chemical processing industry well knows. In some cases, the hardware and process design may represent a minor proportion of the technology. The ability to operate the system properly represents the balance.

Proper management of a waste handling facility starts with adequate identification of the wastes being handled. This represents a significant challenge, since no other chemical processing industry has to deal with this variety of feed streams, all variable in nature.

The need to identify waste streams properly in turn implies the need to work closely with the generator of the waste. The marketing activity of the waste management company must be highly service oriented and somewhat technically oriented, in order to ensure that the wastes are properly handled.

Proper handling must include transportation in the waste management system model. Transportation closes the loop between the generator and the disposal activity. It involves specialized equipment and experienced drivers. Transportation requires the same care and attention that the disposal activity does, and represents an integral part of the systems concept.

Technology is of fundamental importance in the proper handling of industrial wastes. The technology required to solve Ontario's industrial waste problems is either in place or is readily available, and therefore, does not constitute a barrier to solving the problem.

Economics dictate that the treatment and disposal of industrial wastes at central facilities is preferable to treatment at each point of generation. This depends, of course, on the type and volume of wastes available for treatment. A waste stream with a volume of 100,000,000 gallons per year would justify a capital expenditure of approximately \$15,000. In many cases, \$15,000 would not even cover the costs of an engineering design, much less the cost of a treatment facility. For a stream of 1,000 gallons per year, the economics may favor on-site treatment depending on the degree of treatment required, variability of volume and quality, and the availability and cost of off-site treatment facilities.

Obviously, many small companies do not possess the know-how or the financial resources to treat their own wastes. Large companies may be able to justify building treatment facilities for large volume, dilute waste streams, but require off-site facilities for small volume, relatively concentrated waste streams, such as a boiler acid wash stream. Other benefits that are derived from central waste treatment facilities are:

1) Decreased environmental risk, and better monitoring capability

2) Employment of advanced technical processes

3) Increased opportunities for resource recovery

Resource recovery is becoming increasingly important, with current economic pressures for conservation of our resources. In many cases the clean-up of the environment leads to opportunities to recover saleable commodities from wastes. Government environmental policy that forced metallurgical smelters to remove sulphur dioxide from their stack gases has led to a multi-million dollar sulphuric acid industry. Sulphuric acid is now being produced in Northern Ontario for export to the United States and even to trans-ocean markets. On a smaller scale, waste pickle acids can be recycled for use by sewage treatment plants for phosphate removal. Spent caustics are being sold by oil refineries to kraft mills. Used crankcase oils are being collected for energy recovery. Central waste handling plants can facilitate the recycling process by pooling together similar waste streams from a large number of small producers and treating the combined large volume streams for resale.

Why, then, with all their benefits, does Ontario not have a comprehensive central waste treatment facility? The answer is economics: the existing market will not support it.

The cost of a comprehensive treatment and disposal plant is high -- about $15 to $20 million for a grass roots facility. This could be reduced to $10 million by adding on to an existing facility.

The investment required surprises, and discourages, many people. But after all, we are talking about a chemical refinery of some complexity. It must include at the minimum:

- A well equipped laboratory for quality control of wastes coming in and recycled products going out;
- Enclosed receiving facilities for solids and liquids in bulk, in drums and even in small containers;
- Tankage capable of holding 2 million gallons of a variety of liquids;
- Unit processes for treating chemical wastes in order to detoxify, neutralize, filter and recover where feasible;
- Processes for ultimate disposal including secure landfill, deep well disposal and incineration.

An investment of $10 million may now seem rather low. It certainly is low when compared with the investment being made in solid waste handling facilities. For instance, the Ontario government's Centre for Resource Recovery in North York will cost $14 million.

And even at double or triple the cost of $10 million, the investment is much less than what would be required if each generator had to establish his own treatment and disposal operation.

To support such an investment, revenues available to the waste management industry would have to be doubled. Clearly, as long as low-cost landfill disposal is permitted, waste generators have little incentive to use, and pay for technically sophisticated and environmentally desirable methods. Adequate treatment and disposal costs are many times higher than disposal in landfill sites. The problem is compounded by waste haulers who, equipped with Waste Management System Certificates, sometimes maximize profits by utilizing the cheapest outlet available. It is a fact of life that advanced waste treatment and disposal techniques cannot compete economically with dumping into sewers, landfill sites and quarries.

Even if the landfill sites were closed to hazardous wastes, the Ontario market will not support an investment of $10 million. The available volume is relatively small, and therefore average prices would have to increase substantially to generate an adequate return for the added investments.

As prices increase, the waste generator has a number of alternatives to consider:

(a) Volume reduction through change of process
(b) Construction of on-site treatment facilities
(c) Re-use or recycling of waste streams
(d) Use of disposal outlets outside of Ontario.

The long-term impact of a price increase is a reduction in volume available to the waste management industry, and hence the revenues are not altered significantly. At the same time, there is a significant loss of benefit to the generator because of the higher cost of off-site disposal or other alternatives that may have to be implemented because of the higher prices.

In addition to the technical and economic aspects, one must consider the political and social implications of environmental policy. An electricity hungry society creates formidable opposition to proposals for hydro lines. A society that depends on air transport blocks airport proposals. Therefore it is not surprising that projects for waste handling facilities create much public resistance. Environmental Assessment hearings are becoming lengthy and expensive for industry, and politically embarrassing to the government in power. Proposals involving zoning changes can take two years to resolve, and the outcome is always uncertain.

Government must take action to streamline the approvals process. Specifically, there is a need to combine environmental hearings with zoning hearings to speed up the process and reduce the costs involved. At the same time, industry and government have a responsibility to inform the public as to the extent of the problem and the nature of proposed solutions.

To summarize, current waste management practices are inadequate. Too much waste is disposed of without adequate controls and safeguards. The problem is one of economics. What choices, then, are there? There are only four:

1) Maintain the status quo, with increasing reliance on land disposal. This is clearly an unacceptable alternative

2) Force the generators of waste to treat and dispose of their own wastes, regardless of cost. But this can have a direct impact on the ability of the generator to compete in Canada and in export markets.

3) Establishment of a government owned and operated central facility, or with operation contracted out to private industry.

4) Establishment of a central facility owned and operated by private industry, financially supported by government through grants, forgivable loans or tax concessions. This is the recommended alternative.

The situation that has been described is somewhat analogous to the solid waste situation 10 years ago. In 1970, there were approximately 1,800 dumps handling solid waste. Many of these employed open burning as a method of volume reduction. Many of these were closed by government action. By 1974, approximately 60 per cent of the sites were being operated to acceptable standards. The current percentage could be as high as 80 per cent.

At the same time, public participation had a significant involvement in the approval process, and government responded with a strong policy to promote resource and energy recovery from garbage, which was supported by the public.

In 1970, the solid waste management industry was small and fragmented, and many municipalities were handling their own wastes. Considerable consolidation took place, and today private industry is playing a prominent role in the province's resource recovery program. At the same time, government is taking a strong position with respect to the ownership and operation of these recovery facilities.

This is where the analogy ends. In the case of solid waste, government is dealing with a single product and in most instances a single customer. In the case of industrial wastes, there are many products and many customers. In fact, the market is province-wide. Given the degree of complexity it is felt that private industry is in the best position to solve the problem, in response to government leadership.

Often people in business and industry deplore (with some justification) the involvement of government in their operational areas. But I don't think there is any doubt that in this case only a government fulfilling its role of representing all elements in our society, can set the waste management standards required to protect our environment and our health and to consider the costs involved. Equally important, a government is in the best position to educate the public about the necessity of establishing central treatment and disposal facilities, so that the industry does not have to face constant opposition to every construction project put forward. Politics is still the art of the possible.

In considering future environmental policy, we have to keep in mind the following points:

1) Processing of wastes at a central facility is preferable to treatment and disposal at each point of generation.

2) Recycling of wastes is preferable to incineration and surface treatment.

3) Incineration and surface treatment are preferable to deep well and secure landfill disposal.

4) Deep wells and secure landfills should be used only for disposal of detoxified brines and residues, respectively.

5) Sanitary landfills should not be used for the disposal of hazardous industrial waste.

Given a clear economic and environmental framework within which to plan, private industry will respond with the technology and capital to build the necessary facilities. Ontario's industry will then be able to handle its waste in a system that is both affordable and economically desirable. There are no simple solutions -- only intelligent choices.

Waste Materials Exchanges
for Environmental Protection
and Resource Conservation

R. G. W. Laughlin

1. INTRODUCTION

This paper describes a recent study[(1)] undertaken by Ontario Research Foundation on behalf of Environment Canada on the concept and methodology of Waste Materials Information Exchanges. It outlines ORF's recommendations for the establishment of a Canadian Waste Materials Exchange based on the information gained during the study, and discusses how this might affect the established secondary materials industry.

2. CONCEPT

The concept of the waste exchange is predicated on the old adage that "one man's meat is another man's poison", or as it might be restated today, "one man's garbage is another man's gold". Waste industrial materials may well prove to be a useful feedstock for another company. In order that companies may consider using a waste material, they must first know of its existence. This is achieved by a Waste Materials Exchange which may be defined as a vehicle by which the availability of waste materials or by-products is made known to potential users. Other less formal definitions suggested to us during the course of the study were "industrial flea market" and "industrial bargain hunters' press".

Large companies with many processes and skilled chemical engineers are likely to find numerous recycling opportunities within their own manufacturing facilities. However, even engineers in large national companies are not likely to recognise all waste transfer opportunities outside of their own industry. Thus the concept of spreading the word about the availability of particular waste streams is attractive in that it increases the number of people examining possible uses for the waste.

The basic philosphy behind the operation of a waste materials exchange is to help return as much of what is now regarded as waste to an alternative industrial use. This may be achieved directly by one industry directly "buying" waste as a substitute raw material, or it may occur via some intermediary such as a reprocessor or scrap dealer.

The objectives for such an exchange are:

1. To save valuable raw materials;
2. To save energy by not having to process raw materials;
3. To avoid environmental damage:
   (a) in the winning of raw materials and energy
   (b) in the avoidance of having to dispose of the waste.

Philosphy is fine, and it is unlikely that anyone would disagree with the basic reasoning behind the exchange. Nevertheless, no one is going to engage in exchanging of wastes unless it is feasible to do so both technically and ECONOMICALLY.

In assessing the economics of waste recycling, the potential savings in not having to buy virgin raw materials by one firm, and not having to dispose of a waste, by another, must be weighed against additional costs in transportation of the waste material between generator and user, and process modification required to utilize a less pure material or in reprocessing of the material.

The costs of virgin raw materials should reflect:

- The scarcity of the material
- The accessibility of the material to the market
- The energy requirement to produce the material

Scarcer, less accessible, energy-intensive materials should carry higher price tags than plentiful, accessible, low energy-consuming materials. Materials with high initial costs are generally good candidates for the waste

materials exchange, and reuse of these commodities would fulfil objectives 1, 2 and 3a as stated above.

Disposal costs for waste materials are dependent on the disposal techniques for each particular waste as required by government legislation. Increasingly stringent industrial waste disposal legislation is being introduced in both Europe and North America at the present time. In all cases the first category of waste materials to be affected by this new legislation is "hazardous" or environmentally deleterious wastes. These will require disposal practices which will ensure their complete passivation. Costs for treatment and disposal of wastes are likely to be 5 to 10 times higher than for landfilling. Thus the most likely materials for recycling from this economic point of view are the environmentally deleterious wastes. Their reuse would fulfil the objective 3b as stated above.

It would be very naive to imagine that a waste exchange will eliminate all problems of waste disposal. There are many waste materials for which no use is ever likely to be found. A recent study[2, 3] of waste exchanges by Arthur D. Little for the U.S. EPA concluded that, of a total industrial waste (generated by 14 major industrial sectors in the U.S.A.) of about 206 million metric tons per year, 3% has potential value - a total of 6 million metric tons. Using a 10:1 ratio for Canada, some 600,000 metric tons of waste might be considered potentially transferable.

Wastes generally recognized as having components of potential value include those having high concentrations of recoverable metals, solvents, alkalis, concentrated acids, catalysts, oils and combustibles. A. D. Little's report included the following estimates of percentages of waste potentially transferable from four industry groupings:

S.I.C. No.	Industry	Transferable Wastes
2911	Petroleum Refining	63%
2865) 2869)	Organic Chemicals	22%
2884	Pharmaceuticals	17%
355	Small Industrial Machinery	17%

In their analysis of likely waste transfers in the Chemical Industry, A. D. Little concluded that transfers of waste materials are more likely to take place:

- From larger companies using continuous processes to smaller companies using batch processes
- From basic chemical manufacturers to formulators; and
- From industries with extremely high purity requirements (e.g. pharmaceuticals) to those with lower purity requirements (e.g. paints).

The waste materials exchange will most probably be effective in encouraging transfers between different industries rather than internally within one industry where personnel are more aware of recycling opportunities.

3. THE STUDY

With the concept of waste exchange defined we proceeded to study existing waste exchanges. These are of two basic types:

1. Information exchange only (passive)
2. Information plus materials handling (active)

Most of the existing exchanges in Europe and North America are of the information-only type, and have settled into a good working relationship with existing active materials-handling organizations such as scrap dealers, reprocessors and disposers. The information made available to these organizations is useful to them in locating potential supply and demand opportunities.

Organizing an active materials handling exchange may incur some animosity from existing secondary materials handlers, as this is definitely beginning to encroach on their industry. The costs involved in establishing

and operating the materials-handling type of exchange are much higher both in capital investment and operating charges. Most waste materials handlers at present, either scrap dealers or reprocessors, tend to concentrate on particular commodities. This is directed by the need of these companies to make a profit, which is their raison d'être. Any environmental protection and resource conservation achieved through their activities is of secondary importance to them.

Waste materials which pass through an active exchange do so not only physically and economically, but also legally. The responsibility for the wastes' characteristics, as far as any user is concerned, lies with the waste exchange. This may require a fairly sophisticated laboratory facility if the exchange is dealing in chemical wastes. For an information-only exchange no legal responsibility rests with the exchange; the transaction is between the generator and user of the waste, the exchange only having served to introduce the two parties.

It was felt that the basic need in Canada was for an information-only type of Waste Materials Exchange, so that the remainder of the study concentrated on this type of organization.

A total of 17 existing waste exchanges were contacted in Europe and in North America. These are listed below and are divided into 5 major categories.

1. Those Operated by Industrial Societies for their Membership

Verband der Chemischen Industrie (VCI), West Germany
Schweizerische Gesellschaft für Chemische Industrie (SGCI), Switzerland
Ecochem Bourse, Belgium
Vereniging van de Nederlandse Chemische Industrie (VNCI), Holland
Associazione Nationale dell Industria Chimica (ANIC), Italy

National Industrial Materials Recovery Association (NIMRA), U.K.

2. Those Operated by Organizations such as Chambers of Commerce

Deutscher Industrie-und Handelstag (DIHT), West Germany
Handelskammer der Ober Österreich (HKOÖ), Austria
St. Louis Regional Commerce and Growth Association, U.S.A.
Iowa Industrial Waste Information Exchange, U.S.A.
Houston Chemical Recycle Information, U.S.A.

3. Those Operated by Commercial Magazines

Nuisances et Environnement, France
Canadian Chemical Processing, Canada

4. Those Operated by Government

Ontario Ministry of Industry and Tourism, Canada
Tennessee Dept. of Public Health, U.S.A.

5. Those Sponsored by Government, Operated by Independent Labs.

U.K. Waste Exchange, U.K.
Nordic Exchange, Scandinavia

Some of the operating characteristics of the exchanges are summarized in Table 1. Since the exchanges have not all been operating for the same length of time, direct comparisons are somewhat unfair.

Of the five basic types, those operated by chambers of commerce in Europe and those sponsored by government and operated independently seem to have generated the greatest activity and interest. The Deutscher Industrie-und Handelstag (DIHT) and the United Kingdom Waste Materials Exchange, types 2 and 5 respectively, seem to be the two most active. The DIHT exchange has the advantage of a legal requirement for all registered companies to belong to their local chamber of industry and commerce. It

thus enjoys a circulation of 700,000 companies for its exchange bulletin.

There is no indication that any of the existing exchanges, apart possibly from the French Exchange, is attempting to achieve economic viability. In the majority of cases the service is free of charge or else a nominal fee is charged, e.g. $5 for three listings on the St. Louis exchange. The French exchange operated through the magazine 'Nuisances et Environnement' charges approximately $20 per listing, which is at the same rate as their other classified advertising. They indicated that this did almost cover the costs incurred in operating the exchange.

The United Kingdom Waste Exchange was initially funded by the British government for a two year trial period with a £70,000 ($112,000) grant. In the case of the Nordic Exchange, the costs of operating the exchange, plus funds for research into waste utilization, are provided by Nordisk Industrifond, an intergovernmental foundation established in 1973 to promote joint industrial research and development among the Nordic countries. The Federations of Industry in Denmark, Norway, Finland and Sweden provide matching funds to assist operation of the waste exchange.

All of the other exchanges are funded by the industry association, chamber(s) of commerce, magazine or government department operating them. In all cases, no definitive information on costs of exchange operation were available. This was a case of the information not being known rather than reticence to release it, the exchange operating costs being adsorbed into the overhead of the sponsoring organization. In most cases an estimate of the manpower requirements were given, on request. However, these were for the most part very approximate.

Almost all of the established exchanges carry listings for both available and wanted wastes. The U.K. has just dropped the wanted section from their latest bulletin. This seems to have been caused by lack of manpower to handle the enquiries coming in for the items listed as wanted. The Nordic exchange includes a section on disposal and treatment capacity for wastes. This seems to be a valuable addition to the bulletin to help serve the needs of the established secondary materials industry.

The Swiss, German, Dutch, Belgian and Italian exchanges, all of which are run by chemical societies, accept only listings for chemicals. The VCI exchange in Germany seems to have the most restrictive criteria for listing on the exchange. They do not list waste oils, paper, plastic, textiles, metals and chemicals, etc., which are date-stamped and no longer current. All of these commodities have established brokers or dealers. VCI has lists of all these dealers, so that, when an offer comes in for one of these wastes, the list of dealers for that commodity is sent to the potential lister, and he is advised to contact the one nearest to him. The U.K. exchange lists most items submitted to it. It does, however, encourage people to use the NIMRA exchange for such items as scrap metals and used equipment. The other exchanges seem to accept most commodities for listing.

All but two of the exchanges guarantee anonymity for companies listing wastes available or wanted by assigning code numbers to the waste listing. Interested parties submit requests to the exchange for a particular item, identified by code number. The exchange forwards the request to the lister. The two exceptions were exchanges run by the National Industrial Materials Recovery Association in the U.K. and the Austrian Chamber of Industry and Commerce exchanges. In these exchanges names and addresses of listing companies are published.

In Figures 1 and 2 the cover and one page of listings from a recent U.K. Waste Exchange Bulletin are reproduced. The U.K. is divided into 7 geographic regions, each designated by a letter. This letter is used in the listings of wastes as part of the code number.

Experience of the European exchanges has shown that between 10% and 30% of the wastes listed are transferred. For example, in the U.K. where 8,864 enquiries had been received for 1,104 of 1,310 wastes listed, 174 wastes were known to have actually been transferred. An analysis of the value of the first 125 wastes transferred, based on the "as new" value of the raw materials they replaced, showed they represented savings of £5 million (approximately $8 million). The U.K. Waste Exchange is the only one which has made a serious attempt to determine the value of the service it offers.

Because the exchanges offer a confidential service to their users, information on individual waste transfers is not available. The Nordic Exchange has put together an analysis of their operations by categories which shows the relative success rates of transfers occurring. This analysis is reproduced as Table 2. Acids, many of which are dilute, show no signs of transferring. Comment on the difficulties of finding uses for waste acids were repeated by many of the exchange operators. Alkalis, on the other hand, seem to be more in demand, and the U.K. exchange has been successful in placing large quantities of caustic soda.

An assessment was made of the impact of strict waste disposal control legislation on the operations of a waste exchange. It was concluded that, since insistence on disposal in an environmentally acceptable manner will undoubtedly increase the cost of waste disposal, the alternative of reuse will become economically more attractive. Thus, strict controls will increase the activity of a waste materials exchange.

A survey was made to determine the reaction of the manufacturing industries to the concept of a waste material exchange in Canada. In the overwhelming majority of cases, the response was extremely enthusiastic. Industrialists contacted felt that this type of information exchange would be helpful to them. Several had already tried on an informal basis to find markets for some of their wastes or by-products.

4. RECOMMENDATION FOR THE ESTABLISHMENT OF A CANADIAN WASTE MATERIALS EXCHANGE

As part of the waste exchange survey, the operations of two existing Canadian waste exchanges were examined. The magazine, Canadian Chemical Processing, has been publishing letters in a section on Waste Exchange since October, 1973. To date 16 letters have been published, 9 offering wastes, 5 requesting wastes and 2 commenting on the waste exchange. It was felt during the study that an existing technical magazine may not be the best medium for a waste exchange. The audience for a technical magazine is based on the major topic covered by that publication. This

audience may not be the optimum for information about a waste exchange. A technical journal is unlikely to reach smaller companies who do not have people of high technical expertise on staff.

The Ontario Ministry of Industry and Tourism has published two "Profits from Waste" bulletins containing a total of 144 items under 6 categories: (1) Textiles, (2) Paper, (3) Plastics, Chemicals, etc., (4) Metals, (5) Food and (6) Wood and Wood products. The major criticism which can be made of this exchange is that it is directed mainly toward secondary manufacturing rather than primary producers. Much of the material listed might be more accurately described as scrap rather than industrial waste.

Of the two government exchanges, the M.I.T. exchange is the only one that has received any listings. The success of the M.I.T. exchange in attracting listers from the secondary manufacturing industry reflects favourably on the credibility of the Ministry of Industry and Tourism with this segment of Ontario Industry. This exchange serves only industries in Ontario.

It was our opinion that the two existing Canadian Waste Exchanges are not maximising the exposure of available industrial waste materials to all industries in Canada. It was therefore recommended that a Canadian Waste Materials Exchange be established, based on the following format:

4.1 One Exchange Should Serve All of Canada

Since only information is being exchanged, geographic distance should not be a problem. It minimizes costs and maximizes the technical services which could be made available. It may also enjoy a higher profile and thus generate more interest. It is of particular convenience to large multi-plant companies with central environmental co-ordination and/or purchasing departments.

4.2 It Should Be An Information-Only Exchange

The exchange should not actively participate in the buying, selling and handling of waste materials. It should only be involved in the exchange of information about the materials.

4.3 It Should Cover All Industries

Exchanges of wastes are more likely to occur between industries than within a single industry. They are also more likely to transfer from a large company to a smaller, more flexible company. The waste management processing industry should be included as it has a key role to play in the successful transfer of wastes.

4.4 Participation Should Be Free During a 2-Year Trial Period

It is not possible to demonstrate the viability of a waste materials exchange in Canada prior to its establishment. To maximize the number of participants in the venture, it is suggested that the service be free for a 2-year trial period, but thereafter be self-sustaining.

4.5 Sponsorship During the Trial Period Should Be by the Federal Government

Sponsorship and operation of the waste exchange should be (in order of preference) as follows:

1. Sponsored by Environment Canada and/or Department of Industry, Trade and Commerce, operation contracted out, or
2. Sponsored and operated by Environment Canada, or
3. Sponsored and operated by the Department of Industry, Trade and Commerce.

Financial sponsorship will be required during the first two years of operation and it should be available during

the first year of self-sustaining operation in case this goal is not realized.

4.6 The Exchange Should Issue Its Own Bulletin

Because of the wide variations between companies which the exchange should cover, it was not felt that any existing publication would reach all of them. The development of a mailing list will be a first priority for the exchange.

4.7 The Bulletin Should Issue 6 Times Per Year

January, March, May, July, September and November.

4.8 The Bulletin Should Have 3 Sections

1. Wastes Available
2. Wastes Wanted
3. Reprocessing and Transportation Services Available.

The first two sections should offer anonymity to listers. The third would be on a non-confidential basis.

4.9 Wastes Should Be Listed in Successive Bulletins

Removal of a waste from the list should not be put into effect until it transfers, or a request from the lister to remove it is received. Possibly, if distribution of the bulletin is not growing, a maximum time period of, say, two years should be applied to listings not generating interest.

4.10 Data Storage and Handling Should Be Mechanical

One existing exchange uses a computer data handling system. It is not felt that this is necessary, apart possibly from the generation of a mailing list. A relatively simple mechanical data handling system will allow the recall of necessary information.

4.11 Exchange Operators Should Actively Promote The Waste Exchange Concept

Promotion via the popular media as well as through technical journals, conferences, etc., will increase interest in and activity of the waste exchange. Government departments at the federal, provincial and regional levels should be encouraged to promote the use of the exchange.

4.12 Exchange Operator Should Offer Technical Help on Waste Reuse

The exchange operator should have a technical background in waste processing and reuse, and offer advice if requested.

4.13 The Exchange Should Not Be Involved in Negotiations Between Lister and Enquirer

The exchange, being only an information clearing-house, should not be involved in negotiations on a waste transfer. Involvement might mean some legal liability for the exchange to guarantee the quality of wastes listed. Operating only as an information source, no liability rests with the exchange. To assess the effectiveness of the exchange, the lister will be asked to inform the exchange if they follow up on an enquiry, and then when a transfer has occurred.

4.14 The Exchange Operator Should Recommend Areas for R and D

By evaluating the wastes listed and enquiries received, the exchange operator should be in an excellent position to suggest research and development programmes in the area of waste reuse. This should be particularly applicable to wastes which generate a number of enquiries but are not successfully transferred.

4.15 The Exchange Operator Should Evaluate the Exchange

To assess the "success" or "failure" of the waste materials exchange in quantitative terms, it is suggested that the "as new" value of the raw material which the waste has displaced is a measure of its effectiveness. As an alternative, the weight or volume of wastes exchanged may also be computed. Credit for continuously-arising wastes which are transferred should be taken on an annual basis, for each year of operation of the exchange.

A logo has been designed to identify all correspondence and bulletins issued by the Canadian Waste Exchange. This is illustrated in Figure 3 which is a simulation of the front page of the first bulletin of the Canadian Waste Materials Exchange. The map which appears in this Figure divides Canada into 23 regions. These regional identifier letters will be used in the code numbers to show where the waste is being generated. The lister will be given the option of more closely identifying his location if he wishes to and feels it would not jeopardize the confidentiality of the listing.

5. EFFECT ON THE ESTABLISHED CANADIAN SECONDARY MATERIALS INDUSTRY

Discussions were held with both the Waste Management processing industry, and with the Canadian Association of Recycling Industries (CARI) representing the scrap dealers and brokers.

The Waste Management Processing Industry, represented by firms like Tricil, Interflow, Forsythe Lubricants, Oakside Chemicals, etc., all felt that the establishment of a Canadian Waste Exchange would be beneficial to their businesses, in identifying new opportunities for both feed to their processes and markets for their products. These concentrating more on disposal felt that a minor initial reduction in business might result, but that, in the medium-to-long term, the effects would be beneficial.

CARI, on the other hand, were initially less enthusiastic about the exchange concept. CARI's members deal almost exclusively with scrap metals and paper fibre. They feel that their members have identified all of the major supplies and markets for scrap metals and paper, and that a waste exchange might disturb an already very unstable market-place. When it was pointed out that the aim of the waste exchange was at major industrial waste problems and certainly not at scrap metal and paper, they agreed that there was a need for stimulation of reuse of these materials. We discussed not accepting listings for paper products and metal scrap, but decided against a formal ban, rather a discouragement in the description of the aims and operation of the exchange. The exchange operator and CARI will review the listings in the first few bulletins and reassess the position at that time. CARI members will receive all of the information about the exchange and its bulletins. We are confident that they will find that the operation will complement rather than be detrimental to their market-place.

6. PRESENT STATUS OF THE EXCHANGE

Having completed work on the development of the methodology for an exchange operation, based on the review of existing operations, we were requested to undertake the further work to facilitate the actual implementation of an exchange operation. This additional work is described in a follow-up report[(4)] which deals with the publicity aspects of the proposed operation. It also includes a mailing list of 42,000 companies drawn up for initial publicity purposes.

Both reports have now been received by the Waste Management Branch, Fisheries and Environment Canada, and the recommendations presented therein have been used by the Branch in their development of a contract work statement. It is their intention to sponsor the operation of a national waste materials exchange for a two-year trial period, after which the exchange, if successful, should become self-supporting.

The Waste Management Branch, in conjunction with the Department of Supply and Services has solicited expressions of interest and contract proposals from a number of proponents, and will soon be awarding a contract to commence the operation as per the study recommendations. It is anticipated that the exchange will be in operation by September 1, 1977. The first bulletin should be issued in November, 1977.

If anyone would like to be put on the mailing list, prior to the commencement of the exchange operation, you are requested to write either myself or Mr. Hans Mooij of the Waste Management Branch.

REFERENCES

1. Laughlin, R. G. W., and Golomb, A., "The Methodology for the Operation of a Waste Materials Exchange in Canada". A study prepared for the Solid Waste Management Branch, Environment Canada, under Contract Number 06SS KE 204-6-EP13. Final Report, January 1, 1977.

2. Chemical Engineering Progress 72 (12) pp 58-62, December 1976.

3. "Waste Clearinghouses and Exchanges, New Ways for Identifying and Transferring Reusable Industrial Process Wastes". Report prepared by Arthur D. Little Inc. for the U.S. Environmental Protection Agency under Contract Number 6B-01-3241, October, 1976.

4. Laughlin, R. G. W., "Extension of Waste Materials Exchange Study: Publicity", prepared for the Solid Waste Management Board, Environment Canada, under Contract Number 06SS KE 204-6-EP13. Report dated March 31, 1977.

FIGURE 1 MAR 23 1977

Bulletin

UK Waste Materials Exchange

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On the map the country has been divided into the seven geographical regions listed.
In the Bulletin listing the area letter has been added to the end of the reference. Thus AA118E is an available item in area E.

A Scotland

B Northern Ireland

C North of England

D West Midlands and Wales

E East Midlands and East Anglia

F Central Southern and South East England

G West of England

There are two forms at the back of the Bulletin:

Contact Request Form

To be used for notifying an interest in obtaining the available materials listed.

Notification Form

To be used for notifying available items for inclusion in the next issue of the Bulletin. It should however be realised that scrap metals, second hand equipment and related materials for which adequate commercial markets already exist are not accepted for entry in the bulletin.

Please note that contact is made by sending the name of the person who wants the waste to the company who advertised it in the bulletin. The identity of the company wherein the arising occurs is never disclosed by the Exchange, and commercial arrangements are made directly between the companies, not through the Exchange.

UK Wast Materials Exchange, PO Box 51, Stevenage, Herts SG1 2DT
Telephone: Stevenage (0438) 3388

FIGURE 2

SECTION A: MATERIALS AVAILABLE

REF R	QUANTITY		ACIDS & ALKALIS
AA030C	200000	GL/W	10-12% CAUSTIC SODA WITH 4% SILICA
AA039F	25000	TN/Y	18% SULPHURIC ACID WITH 48% AMMONIUM SULPHATE
AA040G	25	TN/W	SULPHURIC ACID TAR FROM HYDROCARBON OIL REFINING
AA110F	10	TE/W	60% SULPHURIC ACID,5% HYDROCHLORIC ACID,NO ORGANIC CONTM
AA209D	1500	GL/D	14% AQUEOUS AMMONIA WITH 7% METHANOL
AA268F	15000	GL/D	KIER LIQUOR,3% CAUSTIC SODA PLUS SODA ASH
AA270E	3	TN/D	CALCIUM HYDROXIDE/CARBONATE CAKE,55% MOISTURE,5% NITROGN
AA278F	4	TN/M	CAUSTIC SODA SLAG (LUMPS) CONTAINING ZINC
AA307F	500	GL/W	10% CAUSTIC LIQUOR,20% ORGANIC CHEMICALS,10% SOLVENTS
AA461F	3000	GL/W	WASTE ACID,5% SULPHURIC,3% HYDROCHLORIC,1% NITRIC
AA644C	40000	GL/W	45% SULPHURIC ACID WITH 3% NITRIC ACID
AA655F	3000	GL/M	10 % AQUEOUS SOLUTION AMMONIA
AA682C	12	TN/Y	PHOSPHOROUS ACID WITH SOME ORGANICS & CHLORIDE
AA716D	15000	GL/W	4/10% SULPHURIC ACID WITH IRON SULPHATES
AA747F	40000	GL/W	15% SULPHURIC ACID,CLEAN,CONTAINS 0.2% CHLORIDE
AA814D	30	TE/Y	50% ACETIC ACID CONTG TRACES PHOSPHORIC ACID
AA888D	30	TE/W	SULPHURIC ACID 80% W/W CONTNS SMALL AMTS POLYSULPHONATES
AB091C	1500	TN/M	30% SULPHURIC ACID,45% AMMONIUM SULPHATE SOLUTION
AB172F	60000	GL/W	4% HYDROCHLORIC ACID - SMALL AMOUNT METALS
AB382D	1000	LT	CONC HCL IN CARBOYS
AB405F	15	TE/M	PHOSPHOROUS ACID,50% AQUEOUS EX ACID CHLORINATION
AB410C	3000	GL/M	10% CAUSTIC SODA,10% POLYSULPHIDES,10-20% NA ALUMINATE
AB412C	1000	GL/M	10% NITRIC,10% HYDROFLUORIC,5% SULPHURIC ACIDS +NI,CR,FE
AB413C	1000	GL/M	5% SULPHURIC,2% CHROMIC ACID PLUS UP TO 2% ALUMINIUM
AB429D	12000	GL/M	15% W/W SULPHURIC ACID CONTAINING 1.2% ALUMINIUM
AB471E	1000	GL/M	SULPHURIC ACID 25%/ISOPROPANOL 75%
AB543F	14	TE/M	40% SULPHURIC ACID - SUITABLE FOR EFFLUENT TREATMENT
AB544F	4	TE/M	30% HYDROCHLORIC ACID
AB587D	1500	GL/W	12.5% SULPHURIC ACID WITH 15 G/L ALUMINIUM SULPHATE
AB588D	3500	GL/W	AMMONIA SOLUTION - 10%
AB600D	5000	GL/M	5 - 10% CAUSTIC SODA WITH 10 - 15% ALUMINIUM
AB671D	12480	KG	CAUSTIC SODA - SOLID U SHAPED
AB676A	7000	GL/D	3-5% CAUSTIC SODA SOLUTION CONTAINING 0.5% SULPHIDE
AB682D	10000	GL/W	4% CAUSTIC SODA,SETTLED MERCERISER WASTE
AB707C	11	TE/W	55% SULPHURIC ACID,DARK BROWN & SOME CHARRED ORGANICS

REF R	QUANTITY		CATALYSTS
AA024C	25	TE/Y	SPENT CATALYST, 4-5% VANADIUM PENTOXIDE
AA173F	100	TE	NICKEL CATALYST 3-5% NICKEL
AA505E	30	TN/M	SPENT CATALYST,MAINLY PARTICULATE ALUMINIUM SILICATE
AA507C	17	TE	ZINC ACETATE CATALYST (UNUSED) APPROX 68%NORIT CARBON
AA538F	300	TN	NI&CO-MO HYDRODESULPHURIZING CATALYSTS,NEW OR RE-USABLE
AA539F	200	TN	NEW,RE-USEABLE,SCRAP STEAM-REFORMING CATALYST 4-17%NI
AA540F	150	TN	RE-USEABLE WATER GAS SHIFT CATALYST,CHROMIA-IRON OXIDE
AA702C	4183	KG/Y	NICKEL/ALUMINIUM ALLOY FOR CATALYST
AA703C	335	KG/Y	RANEY NICKEL CATALYST
AA704C	200	KG/Y	NICKEL CATALYST
AB042D	50	TN	PELLETISED CATALYST,5% VANADIUM PENTOXIDE IN SILICA BASE
AB320A	80	GL	PALLADIUM BEARING PLATING ON PLASTIC CATALYST (USED)
AB415C	25	TN/W	SPENT ZINC CATALYST SOLUTION,3% ZINC,7% IRON
AB750D	20	TE	WET ALUMINA CATALYST - 5% CU,0.5% K AS CHLORIDES

REF R	QUANTITY		INORGANIC CHEMICALS
AA008A	13	TE/Y	55% ZINC CARBONATE CHEMICAL WASTE
AA026C	10	TE/M	LUMPY HARD TITANIUM DIOXIDE
AA051F	500	TE/W	85% PURE CALCIUM CARBONATE, 50-60% SLURRY
AA059C	10000	TN/Y	10% SODIUM SULPHATE SOLUTION
AA060E	40	TN/W	16% AMMONIUM NITRATE+AMMONIA+1%GELATIN SOLUTION
AA065E	80	TN/Y	MIXED LEAD CHROMATE/MOLYBDATE RECOVERED PIGMENTS
AA067D	2000	TN/Y	DAMP CALCIUM SULPHATE FILTER CAKE
AA073F	600000	TE/Y	PHOSPHO-GYPSUM FROM PHOSPHORIC ACID MANUFACTURE
AA074F	6000	TE/Y	SODIUM FLUOROSILICATE FROM PHOSPHATE MANUFACTURE
AA075F	3400	TE/Y	OXYGEN BY-PRODUCT OF ELECTROLYSIS
AA102C	125	TE/Y	POTASSIUM ALUMINATE IN 30% KOH (RATE AS KOH)
AA111F	20000	GL/W	MANGANESE SULPHATE SLURRY (= 17 TN ELEMENTAL MANGANESE)
AA148E	400	TN/W	PPTD CALCIUM CARBONATE RESIDUE FROM TAR PROCESSING
AA168D	9	TE/W	DAMP FILTER CAKE,CA & AL PHOSPHATES,SULPHATES&NITRATES
AA205D	16	TE/D	FILTER CAKE,30/10% CA SULPHATE,CARBONATE,6%IRON OXIDE
AA208C	1000	GL	NICKEL SULPHAMATE SOLUTION APPROX 68 G/L METAL CONTENT
AA218F	4	TE/M	LEAD CARBONATE CAKE, 60-65% LEAD
AA277F	2	TN/M	LEAD CHLORIDE SLAG (LUMPS) 70% LEAD + BISMUTH & IRON
AA401D	500	GL/D	SODIUM SULPHIDE/HYDROXIDE SOLTN,BOTH 8-10%
AA452D	40	TE/M	DILUTE AMMONIUM SULPHATE SOLUTION
AA467D	100	TN/W	SALT SLAGS NACL 30%,KCL 10%,AL OXIDE & INSOL FLUORIDES
AA472D	6190	KG	SOLIDIFIED SODIUM NITRATE,.05% NAF,.09% NACL,.09% KCL
AA508C	45	TN/W	ELEMENTAL SULPHUR,CONTAM WATER & FERROUS HYDROXIDE(20%)
AA517C	75	TN/Y	30% ZINC CARBONATE CHEMICAL WASTE
AA518C	6	TN/Y	60% MERCURIC SULPHIDE CHEMICAL WASTE
AA519C	100	TN/Y	IRON OXIDE PASTE
AA536A	48	KG	POTASSIUM CARBONATE ANHYDROUS PURE
AA545F	250	KG/M	30% CADMIUM CARBONATE SLURRY
AA614C	400	GL/M	COPPER SULPHATE SOLUTION
AA615C	500	GL/M	PHOSPHATE SLURRY
AA616C	600	GL/M	STANNOUS CHLORIDE
AA654E	10000	GL/W	50 VOL % SODIUM THIOSULPHATE WITH 1/2 % NAOH
AA661D	10	TE/D	SLUDGE 64% WATER 30% CHALK 6% CALCIUM HYDROXIDE
AA662D	18	TE/D	SLUDGE 58% WATER 26% CALCIUM HYDROX 11% CHALK 5% FINE GR
AA665E	5	TE/D	CALCIUM FLUORIDE FILTER CAKE,SOME SILICA & ALKALI
AA673C	800	TN/M	CAUSTIC SULPHIDE LIQUOR 6% SODIUM SULPHIDE
AA674F	5000	TE/W	FINE POWDER,35-45% CALCIUM CARBONATE,15-25% ALKALI SALTS
AA696C	20	TE/Y	PASTE,APPROX 60 T.S,ESSENTIALLY ZINC OXIDE/HYDROXIDE
AA705D	30	TN/Y	SODIUM SULPHIDE (AQUEOUS SOLUTION)
AA706D	300	TN/Y	SULPHUR
AA707D	8	TN/Y	ALUMINIUM CHLORIDE IN HYDROCHLORIC ACID
AA711D	30	TN/Y	PHOSPHORUS PENTASULPHIDE
AA749F	2	TE	POT BROMIDE 95% + LIGHT MAGNESIUM OXIDE 5%, - 100 MESH
AA753D	3000	TE	GROUND BARYTES RESIDUE,CONTAINING 30-40% BARIUM
AA796C	300	TE/W	CALCIUM OXIDE/CARBONATE,30/70%,THRO 25 BS SIEVE
AA797C	100	TE/W	CA HYDROX/OXIDE/CARBONATE,70/20/10,HYDRATION REJECTS
AA803F	250	KG	SODIUM PHOSPHATE ANHY.(MSP)
AA804F	250	KG	MAGNESIUM NITRATE
AA805F	250	KG	DISODIUM PHOSPHATE ANHY.(DSP)
AA886G	540	KG	3 DRUMS WICK GREEN PASTE(LEAD CHROMATE BASE),35% SOLIDS
AA887G	20	TE/M	AMMONIUM CHLORIDE SATURATED SOLUTION REASONABLY PURE
AA953F	150	KG	MOLYBDIC ACID ANHYDROUS POWDER
AB095F	1	CT	VANADIUM PENTOXIDE
AB096F	2	CT	ZANOX CADMIUM SALTS(CONTAINING CYANIDE)
AB097F	2	CT	SODIUM STANNATE
AB098E	2000	GL/D	25% AQUEOUS FERROUS CHLORIDE
AB123D	100	TE/W	CALCIUM OXIDE/SULPHATE,SILICA,ASH (FROM MID 1977)
AB126F	6	TN	SILICA GEL (IN 2 OZ AND 4 OZ BAGS)

canadian waste materials exchange

FIGURE 3

la bourse canadienne des déchets

BULLETIN No.1

SEPTEMBER 1977

The letters of this map are used to identify the geographic region in which waste materials are available or wanted. The letter appears as the last letter in the waste code number.

Les lettres inscrites sur cette carte indiquent la région géographique où des déchets sont disponibles ou demandés. Cette lettre devient le dernier caractère du code de déchet.

Wastes are listed in the bulletin under 10 categories:

1. Organic Chemicals and Solvents
2. Oils, Fats and Waxes
3. Acids and Alkalis
4. Other Inorganic Chemicals
5. Spent Catalysts
6. Metals and Metal Containing Sludges
7. Plastics
8. Textiles, Leather and Rubber
9. Wood and Paper Products
10. Miscellaneous

<u>Listings will appear in the language submitted</u>

Les déchets sont inscrits au bulletin sous 10 catégories:

1. Produits chimiques organiques et solvants
2. Huiles, graisses et cires
3. Acides et alcalis
4. Autres produits chimiques inorganiques
5. Catalyseurs vieillis
6. Métaux et boues contenant des métaux
7. Plastiques
8. Textiles, cuir et caoutchouc
9. Produits en papier et bois
10. Divers

<u>Les inscriptions paraîtront dans la langue de leur soumission</u>

	U.K.	Nordic	German DIHT	German VCI	Swiss (Chem)	Belgian	Dutch VNCI	French	U.K. NIMRA	U.S.A. St. Louis	Canada M.I.T. Ont.	Canada CCP	Italy ANIC	Austria BAB	Austria HKOO	U.S.A. Iowa	U.S.A. Tennessee	U.S.A. Houston
1. Date Started		Nov. 1973	July 1974	Jan. 1973	Mar. 1973	Nov. 1972	Jan. 1972	April 1975	1942	Oct. 1975	Aug. 1975	Oct. 1973	March 1973	July 1974	Feb. 1973	April 1976	April 1976	Dec. 1976
2. Available only to Member (M) or Anyone (A)	A	A	M	A	M	A*	A	M	M	A	A	A	A	M	M	A	A	A
3. General (G) or Specific to Chemical Industry (S)	G	G	G	S	S	S	S	G	G	G	G	G	G	G	G	G	G	S
4. Publication of Lists - Special Bulletin (B) Magazine (M)	B	M	B	B + M	B	B	B + M	M	M	B	B	M	B	B	B	B	B	B
5. Circulation of Lists	4,800	N/A	700,000	N/A	600	1,000	B 90 M N/A	8,000	2,000	900	6,000	11,000	N/A	N/A	N/A	5,000	N/A	600
6. Confidentiality for Lister	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes & No	No	Yes	Yes	Yes & No	Yes	No	No	Yes	Yes	Yes
7. Do Lists Include																		
Wastes Available	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Wastes Wanted	Not Now	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Spare Capacity	No	Yes	No	Not Now	No	No		No	No	No	No	No	No	No	No	No	No	No
8. What is the Cost to Listers	0	0	0	0	0	$25*	0	~$20	0	$5	0	0	0	0	0	0	0	$15/yr bulletin $10/listing
9. Manpower Requirement - Director (man years/year)	0.33	0.02	N/A	0.2	0.05	Negligible	0	0	N/A	0.12	0	Negligible	0.05	N/A	N/A	0.25	N/A	N/A
Secretarial (man years/year)	1.0	0.05	N/A	0	0.1	Negligible	0.05	0.1	N/A	0.4	0.25	Negligible	0.05	N/A	N/A	0.25	N/A	N/A
10. Approx. Average Number of Listings per year of Operation	900	135	5,000	120	35	25	100	150	1,200	120	145	5	25	125	142	113	0	N/A
11. Approx. Average Number of Enquiries per Listing	5.25	1.9	1.6	3.5	0.5	N/A	N/A	3	N/A	2	1.7	2	2.8	N/A	N/A	3.5	N/A	N/A
12. Estimated Fraction of Listings Resulting in Transactions	0.1	0.27	0.34	0.21	N/A	0.1	0.3	N/A	N/A	N/A	N/A	N/A	N/A	0.44	0.55	N/A	N/A	N/A
13. Who Finances the Exchange - Government (G), Chemical Society (S), Listers (L), Chamber of Commerce (C), Magazine (M)	G	G	C	S	S	S	S	L + M	S	C + L	G	M	S	C	C	G	G	C

* Fees charged only to non members of FICB
N/A = Not Available

TABLE 2 - Nordic Exchange

Summary of Two Years of Operation 1973-1975

Waste Category	Percent of Total Listed (%)	Enquiries per Item	Positive Results per Item
1. Plastics	23.7	2.5	0.2
2. Textiles	12.6	4.1	0.4
3. Paper	5.2	2.4	0.4
4. Solvents	6.7	1.2	0.4
5. Acids	7.4	0.2	0
6. Inorganic Chemicals	11.5	1.5	0.5
7. Organic Chemicals	7.8	0.7	0.3
8. Slags, sludges	7.0	2.2	0.2
9. Miscellaneous	18.1	1.0	0.1
	100.0		